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THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

The Society as a body is not responsible for the statements of facts of opinions advanced in papers or discussions. C55

THE JOURNAL

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MEETING IN ENGLAND

Sir William H. White, Hon. Mem. Am. Soc. M. E., President of the Institution of Mechanical Engineers in 1889 when the Society last visited England officially, attended the Spring Meeting at Atlantic City and conveyed to the membership information concerning the perfected arrangements for the Joint Meeting of the Society with the Institution in England, July 26-28.

Upon arrival of the Celtic at Liverpool, Monday morning, July 25, the party will proceed to Birmingham by special train. On Tuesday morning, after an official reception by the Lord Mayor of Birmingham, papers on Handling Locomotives at Terminals will be presented by members of the Society. The afternoon will be devoted to a variety of professional visits and a garden party in the Botanical Garden will occupy the evening. On Wednesday morning there will be a topical discussion on High Speed Tools and Toothed Gearing, with further professional visits in the afternoon and a reception in the evening by the Lord Mayor of Birmingham, held in the Council House. Thursday will be devoted to visits to Coventry, Rugby, Litchfield, Kenilworth and Warwick where the castles will be visited,and Stratford-on-Avon, the entire party being conducted by special train to London in time for the conversazione in the headquarters of the Institution.

On Friday morning, members of the Society will present papers on the Electrification of Railways in the auditorium of the Institution of Civil Engineers. Several garden parties have been arranged for

the afternoon and the Institution dinner will take place in the evening in the Connaught Rooms, the largest dining hall in the city of London. Ladies are invited to this as well as to many of the other events. Visits are contemplated for Saturday to Windsor, the Japanese-British Exhibition and the Garden Club.

On Sunday special services will be held in Westminster Abbey, where seats will be reserved for the membership. It will be possible to make at this time an inspection of the Memorial Window recently erected to an Honorary Member of the Society, Sir Benjamin Baker, one of the three engineers who have been thus recognized. The window is exquisitely wrought and a material addition to the memorials in the Abbey.

The Committee of Arrangements appointed by the Council consists of Ambrose Swasey, Chairman, Charles Whiting Baker, Vice-Chairman, Dr. W. F. M. Goss, Geo. M. Brill, John R. Freeman, and, ex-officio, George Westinghouse, President, Wm. H. Wiley, Treasurer, F. R. Hutton, Honorary Secretary, Willis E. Hall, Chairman Meetings Committee, and Calvin W. Rice, Secretary. This Committee has appointed the following sub-committees: Transportation, Charles Whiting Baker, Calvin W. Rice; Entertainment, George M. Brill; Publishing and Printing, F. R. Hutton, F. R. Low; Finance, Wm. H. Wiley; Acquaintanceship, Dr. W. F. M. Goss. These sub-committees will provide for the material comfort of the party, and arrange for all official matters, including the publication of items of interest in regard to the Society in the daily newspaper on board ship. It is proposed to make the entertainment of the members on their journey across the Atlantic unlike any ever attempted in ocean travel and souvenirs will be presented to the winners of the games, etc., arranged by the committee in charge.

Copies of circulars giving full details in regard to the trip, including contemporaneous events in Europe, such as the Passion Play at Oberammergau and the International Exposition at Brussels, may be secured from the Secretary on application. Accomodations may yet be obtained from the White Star Line by any members who have failed to make an earlier reservation.

TECHNICAL VISITS

In addition to invitations conveyed to the membership some time ago, the following places of technical interest will be open to visits from the membership: In the Grand Ducal Technical High School

of Darmstadt, the machine construction laboratories, testing apparatus and electrotechnical institutions; Physikalischer Verein of Frankfort-on-Main; Hanover Machine Works of Hanover; de Fries & Cie, Düsseldorf, makers of horizontal boring and milling machines; and Hans Renold, Ltd., Manchester, England, makers of driving chains.

INTERNATIONAL EXHIBITION AT ST. PETERSBURG

Following the joint session in Birmingham of this Society with the Institution of Mechanical Engineers, at which a symposium is to be given on the electrification of railways, there is to be an international exhibition at St. Petersburg on the application of electricity to steam railways. This is to be held under the auspices of the Imperial Russian Technical Society, opening from the 15th to the 18th of August and closing three months later. The exhibits are to consist of rolling stock, apparatus for the equipment and handling of trains, drawings, photographs, descriptions of central stations, both steam and water power, drawings, models of track and roadway, data upon transmission lines, different systems of distribution, equipment of repair shops, general information upon cost of operation, railway exploitations under way in Europe and America, statistics, etc. There will be a special track, two miles long, for the trial of electric and motor cars.

ST. LOUIS MEETING, MAY 28

A meeting of the local members of The American Society of Mechanical Engineers with the Engineers Club of St. Louis was held Saturday evening, May 28, in the Club rooms, 3817 Olive St., St. Louis, Mo. Prof. Edw. C. Schmidt, associate professor of railway engineering at the University of Illinois, presented his paper on Freight Train Resistance; its Relation to Average Car Weight, also given at the Spring Meeting of the Society. Through the courtesy of the University of Illinois, the Illinois Central Railroad and the Terminal Railroad Association, the railway test car by which the data in the paper was obtained, was brought to St. Louis for the meeting and was open for inspection between 2 and 5 o'clock Saturday afternoon in the Eighteenth Street Yard of the Terminal Association. This car is equipped with all the apparatus necessary for carrying on train resistance experiments, as well as with auxilary apparatus which facilitates the making of locomotive road tests, and during the tests the apparatus within the car makes, autographically upon a chart 36 inches wide, a

record of drawbar pull, speed, time, air brake cylinder pressure, wind velocity and wind direction.

The meeting proved to be one of much interest and was well attended. The paper was discussed by Robert Moore, Past-President of the American Society of Civil Engineers, F. B. Fisher, Prof. H. Wade Hibbard, and others.

BOSTON MEETING, JUNE 1

A meeting of The American Society of Mechanical Engineers with the Boston section of the American Institute of Electrical Engineers and the Boston Society of Civil Engineers was held at Huntington Hall, Boston, on the evening of June 1. A dinner to Lewis B. Stillwell, President of the American Institute of Electrical Engineers, preceded the meeting, at which many prominent in engineering circles in New England were present. Prof. I. N. Hollis, Mem.Am.Soc.M.E., chairman of the committee on the proposed engineering building in Boston, spoke of the studies which had been drawn up of the building. These, he said, were based upon the arrangement of a permanent home for the several societies, clubhouse facilities, a joint library, auditorium, and mercantile headquarters. He was followed by several other speakers who spoke of the advantages which such a building would afford.

At the general meeting, President Stillwell made the address of the evening on the Conservation of our Natural Resources, special consideration being given to the subjects of water power and forestry. An extended discussion of the paper followed in which Prof. Geo. F. Swain, Mem.Am.Soc.M.E., C. T. Main, Mem.Am.Soc.M.E., Henry F. Bryant and Dr. A. E. Kennelly took part.

A REQUEST FOR 1903 POCKET LIST

A copy of the Pocket List for 1903 is needed to complete the files of the Society. Any member willing to furnish a copy will please communicate with Calvin W. Rice, Secretary, at the rooms of the Society.

THE SPRING MEETING

The Spring Meeting was held at Atlantic City, N. J., May 31–June 3, 1910, at the Marlborough-Blenheim, with an attendance of 135 members and 119 guests. The Meetings Committee had arranged a strong professional program and the Local Committee, comprised of Pennsylvania and New Jersey members residing in the vicinity of Atlantic City, under the Chairmanship of James M. Dodge, Past-President, gave a cordial welcome to the visitors and contributed to their pleasure in various ways in a generous and most acceptable manner

In place of the usual reception on the opening evening, there was an informal reunion of members and guests in the parlors of the Marlborough-Blenheim. Henry G. Morris, Chairman, Wm. R. Conard, Kern Dodge, Edward P. Harris, T. F. Salter, and J. A. C. L. deTrampe made up the committee in charge. Throughout the whole convention an air of informality and freedom pervaded, permitting the renewal of friendships and the forming of acquaintances without necessity for attending set functions and without the sense of being formally entertained.

Business and Professional Session, June 1

The meeting of Wednesday morning was called to order at ten o'clock by President Westinghouse and the report of the Tellers of Election to Membership presented as follows:

MEMBERS

Best, W. J.	Cooley, E. S.	Fuller, George W.
Blakeslee, F. A.	Coster, E. H.	Fuller, J. W., Jr.
Brown, Edward W.	Cressler, A. D.	Gallup, David L.
Bryant, William L.	Cummings, Byron	Ganz, Albert F.
Burch, Henry Kenyon	Davis, W. J., Jr.	Hallett, Edwin S.
Carson, W. R.	Doane, John A.	Hammond, John Hays
Chapman, Cloyd M.	Dorward, D., Jr.	Herschel, W. H.
Chapman, H. B.	Ernsberger, M. C.	Hodgson, Alec W.
Clark, Frank H.	Fenn, R. W.	Holmes, U. T.
Cone, H. I.	Frost, Harwood	Kingsley, F.

MEMBERS

Lebrecht, A.
Lester, C. R.
London, Wm. J. A.
Loring, Harrison, Jr.
Lundgren, Chas. G.
McLeod, Adolphus A.
Marot, W. G.
Merrell, Irving S.
Metcalf, Frank H.
Miller, John F. G.
Moody, Lewis F.
Neidhardt, J. Wm.
Oatley, Henry B.
Parr, Harry L.
Paulsmeier, A. C.
Peterson, C. H.
Porter, Hollis P.
Redfield, Snowden B.
Sanford, George R.
Sayer, Eugene Y.
Schlatter, R.
Scollan, John J.
Sessions, F. L.
Shallcross, W. C.
Shaw, Joseph D.
Sperry, Elmer A.
Stevens, Edson M.
Sumner, Eliot
Tenney, Theodore S.
Van Patten, W. E.
Westcott, V. S.
Whiteside, W. H.
Wiggin, R. M.
Winsor, Paul
Wyatt E. W.
Yeomans, Lucien I.
Zowski-Zwierzchowski, [S. T.]

PROMOTION TO MEMBERS

Batten, P. H.
Bishop, Frank
Bursley, Jos. A.
Dietz, Carl F.
Emerson, R. W.
Kennedy, F. L.
King, Roy Stevenson
Mahl, Frederick W.
Marshall, S. M.
Satterfield, H. E.
Young, C. D.
Young, John M.

ASSOCIATES

Burgess, Frank
Cobb, S. P.
Cooley, H. N.
Sears, Frank M.
Thompson, O. C.
Thorn, Charles N.
Whitcomb, Lawrence

PROMOTION TO ASSOCIATES

Hawley, Wm. P.
Henes, Louis G.

JUNIORS

Abrahams, M. L.
Adams, John
Bailey, Alex. D.
Bancroft, Geo. A.
Barnes, Arthur F.
Barron, C. M.
Bedell, E. H.
Bonner, Richard O.
Brady, J. B.
Brown, Walter E.
Burgess, A. Bradley
Carter, Harold Thomas
Casserly, T. D.
Clark, W. Van Alan
Cook, H. H.
Cook, William H.
Corlette, Glen H.
Correa, W. H.
Crute, W. R.
Cunningham, Geo. H.
Davock, H. N.
Dubarry, Ed. G.
Ellenbogen, S. A.
Emerson, R.
Ennis, H. V.
Fekete, Stephen I.
Fisher, J. O.
Foley, Walter J.
Gast, George Fred
Gernandt, W. G.
Gladfelter, H. S.
Grant, Chas. C.
Hall, Dwight K.
Hartley, H. D.
Heidelberg, Fred M.
Henderson, C. T.
Hey, Harry A.
Hood, Warren B.
Husted, C. M.
Keables, Austin D.
Lange, H. B.
Lines, W. H.
McCreery, J. Harold
McKibben, H. B.
Morris, Thos. B.
Mudge, S. T.
Nelson, B. S.
Painter, J. G.
Peper, John H., Jr.
Price, William T.
Roesler, Rudolph

JUNIORS

Ross, Philip L.	Sloane, Charles O'Conor	Thoma, Charles, Jr.
Rowlands, D. D.	Snow, N. L.	Terwilliger, Gerald E.
Rowley, R. L.	Sprau, W. C.	Thoma, Walter
Schoenijahn, R. P.	Stockwell, R. K.	Webster, L. B.
Sharp, J. T., Jr.	Swartwout, Everett W.	Wick, James L.
Sievers, E. J. J.	Taylor, H. B.	Wilson, R. A.
Woodman, Forrest E.		Zachert, A. R.

The following amendments to the Constitution were proposed by the Tellers on Amendment to the Constitution, and adopted by the meeting:

C 10 An Associate shall be thirty years of age or over. He must have been so connected with some branch of engineering or science, or the arts, or industries, that the Council will consider him qualified to coöperate with engineers in the advancement of professional knowledge.

C 11 A Junior shall be twenty-one years of age or over. He must have had such engineering experience as will enable him to fill a responsible subordinate position in engineering work, or he must be a graduate of an engineering school. A person who is over thirty years of age shall not be eligible to membership in the Society as a Junior.

C 45 The Standing Committees of the Society to be appointed by the President shall be: Finance Committee, Committee on Meetings, Publication Committee, Membership Committee, Library Committee, House Committee, Research Committee, Public Relations Committee.

Following this was a discussion on a proposed Bill for Licensing Engineers, introduced in the recent session of the New York Legislature. In explanation, Charles Whiting Baker, chairman of a committee appointed by the Council to investigate the subject, explained that the bill had called for the licensing of all grades of civil engineers, but that afterwards it was extended to all branches of engineering, requiring engineers to pass an examination and pay a license fee of $25 for the privilege of practicing in their profession. The Board of Regents would have authority to appoint a special board of examiners before which every engineer desiring to practice would have to pass an examination. The engineering colleges of New York would be under the control of the same Board of Regents.

It was felt that the passage of such a bill would be injurious and a number of prominent engineers appeared at Albany in opposition and owing to their representations the bill was withdrawn by its promotor, with the understanding that it would be amended and offered at a later time.

The special committee appointed by the Council had met and adopted resolutions upon the subject of the pending bill, substantially as follows:

That it is the sense of this committee that legislation affecting the privileges and status of engineers can be most wisely originated by conference between legislators and representatives of the national engineering societies, and that the attention of legislators proposing legislation be invited to this procedure as natural and regular.

To request the Council of the Society to communicate with the Committee on Education to request the State Assembly that further action on this bill be postponed until after the Spring Meeting of The American Society of Mechanical Engineers, to be held in Atlantic City, May 31–June 3, at which meeting the subject will receive discussion.

To request the Secretary of the Society to confer with his colleagues, secretaries of the foreign technical societies, and seek to obtain such information as possible in regard to the necessity of the possession of certificates of competency, or other forms of license.

At a meeting of the Council just held at Atlantic City, a new Committee of Public Relations was authorized, one of the duties of which will be to act on any further legislation affecting the interests of members of the engineering profession. The movement for licensing engineers is bound to come up repeatedly in the legislatures of the various states and this Society should be prepared to take whatever action may be necessary to protect the interests of the profession as a whole from unwise and injurious legislation. This discussion ended the business meeting and the remaining time was devoted to the professional session.

There were four papers presented on the subject of Machine Construction and Operation. The first, The Shockless Jarring Machine, by Wilfred Lewis of Philadelphia, dealt with a new type of jarring machine in which the shock heretofore transmitted to the ground is absorbed as effective work by the machine itself, saving substantially all ramming time and opening the way to other economies. The paper was discussed by A. E. Outerbridge. E. H. Mumford and F. W. Taylor.

Prof. Walter Rautenstrauch of New York followed with his paper on A Comparison of Lathe Headstock Characteristics, concerned with the determination of the adaptability of a number of engine lathes to the economic performance of a standard task, that

of taking a predetermined area of cut on all diameters of work of mild and soft steel pieces, with high-heat steels, and showed the attempts of different manufacturers to meet the conditions favorable to these steels. Carl G. Barth, F. W. Taylor, Oberlin Smith and John Fritz discussed the paper.

The paper by Prof. A. L. Jenkins, of Cincinnati, on The Strength of Punch and Riveter Frames made of Cast Iron was next presented, giving a résumé of the important theories proposed for the analysis of stresses in straight cast-iron beams and presenting data on tests with small castings similar in shape to punch frames which showed a failure to verify any forumla. The discussors were James Christie, Walter Rautenstrauch, F. I. Ellis, Henry Hess, Oberlin Smith, Wilfred Lewis, J. S. Myers, S. A. Moss, George Westinghouse and John Fritz.

The fourth paper was upon Improved Methods in Finishing Staybolts and Straight and Taper Bolts for Locomotives, by C. K. Lassiter, of Richmond Va., and showed the advantage, in finishing staybolts, of automatically reducing in the center during the threading operations. Turning and facing under the head of straight and taper bolts were also treated. This paper was presented by Col. E. D. Meier, who added a few remarks.

Wednesday Afternoon and Evening

Wednesday afternoon was left free for recreation, roller chairs for the boardwalk being provided by the Local Committee throughout the afternoon. At three o'clock a special car conveyed members and guests to the grounds of the Golf Club at Pleasantville, where those who desired went over the course. Afternoon tea was served by the ladies.

In the evening there was a large attendance at the entertainment on the steel pier for which admission had been arranged. The Committee in charge consisted of Thos. C. McBride, Chairman, Thos. Eynon, James T. Halsey, John S. Muckle, John C. Parker and Wm. R. Webster.

Gas Power Section, Thursday Morning, June 2

J. R. Bibbins, Chairman of the Gas Power Section, called the meeting to order at ten o'clock and a few remarks were made by Secretary Rice congratulating the Section on its activities. Following

the business of the meeting, a paper on A Regenerator Cycle for Gas Engines using Sub-Adiabatic Expansion was presented by A. J. Frith of Chicago, which described a new cycle of 100 per cent theoretical efficiency, caused by the expansion line being steeper than that caused by free expansion, showing an avoidance of the loss of heat by water cooling, which in the older regenerative cycles overbalance the theoretical economy. The paper was discussed by S. A. Moss Wm. T. Magruder and Charles Whiting Baker.

The second paper was on Gas Engines for Driving Alternating-Current Generators, by H. G. Reist of Schenectady, N. Y., and brought out no discussion. The paper dealt with the solution of the problems of obtaining the best parallel operation of alternating-current generators when driven by means of gas engines, the most satisfactory solution being so to design the gas engine as to obtain nearly even rotation.

Two proposed Units of Power by Prof. Wm. T. Magruder, Columbus, O., was next presented and criticized the existing usage, proposing instead the terms boiler-power and gas-power, both of which were defined and described. Discussion was offered by Wm. Kent, H. G. Stott, J. C. Parker and E. D. Dreyfus.

The fourth paper presented was upon Operating Experiences with a Blast Furnace Gas Power Plant, by H. J. Freyn, of South Chicago, Ill., and contained a most complete account of elaborate tests made on the plant, extending over a period of two years. It was discussed by A. E. Maccoun, Jos. Morgan, W. E. Snyder, H. G. Stott, E. A. Uehling, Captain Tarr, Edw. Rathbun, Oberlin Smith and Charles Whiting Baker.

Professional Session, Thursday Afternoon

At the session of Thursday afternoon, commencing at two o'clock, four papers on miscellaneous subjects were presented, the first upon The Mechanical Engineer and the Textile Industry, by H. L. Gantt of New York. This was designed to point out a field and its possibilities in which the mechanical engineer had done little, that of industries which have not ordinarily come under his surveillance. There was no discussion.

A paper on the Elastic Limit of Manganese and other Bronzes by J. A. Capp of Schenectady, N. Y., followed, dealing with the elastic curves of brasses and bronzes, which are smooth curves, gradually bending as stress increases, and showing their lack of relationship to

the elastic limit indicated by the elastic curve. S. A. Moss, F. W. Dean, F. B. Gilbreth and E. A. Uehling discussed the paper.

The Hydrostatic Chord by Raymond D. Johnson, Niagara Falls, N. Y., was next presented. The name hydrostatic chord is given to a novel shape for large pressure conduits the function of which is to produce a tendency in the pipe to round out after the pressure reaches a certain mean value, causing an effort to increase the vertical diameter and tending to lift both the dead weight of the pipe shell itself and the top fill. The paper contended that these defects could be obviated with a shape properly designed on correct hydrostatic principles. There was no discussion.

The last paper was by Prof. Edw. C. Schmidt, Urbana, Ill., on The Resistance of Freight Trains and presented the results of tests made to determine this resistance and fully displayed and examined the test data. T. S. Bailey, W. T. Raymond, S. A. Moss, F. W. Dean, H. G. Stott, G. N. VanDerhoef, H. R. Cobleigh, Wm. H. Bryan, F. J. Cole, W. F. M. Goss and J. B. Blood discussed the paper.

Thursday Evening

On Thursday evening Honorary Membership in the Society was conferred on Rear-Admiral George W. Melville, U. S. N., Retired. At a gathering in the solarium of the hotel, Secretary Rice made formal announcement of the vote of the Council receiving Admiral Melville into such membership, and President Westinghouse voiced the pleasure of the Society in thus recognizing so distinguished an engineer. In replying, Admiral Melville expressed his appreciation of the honor bestowed upon him by his brother engineers. Sir William H. White, Past-President of the Institution of Mechanical Engineers and an Honorary Member of the Society, followed Admiral Melville and spoke of his splendid years of service to his country, of the sort sometimes disregarded by a man's own countrymen because of lack of perspective. He recalled the extraordinary naval experiences which the Admiral had undergone, in which he never at any time flinched from duty, and expressed himself in accord with Admiral Melville's feeling with regard to the honor conferred on him, since he also had been so signaled out by the Society. Walter M. McFarland of Pittsburg then read an address prepared by Admiral Melville for the occasion, on The Engineer's Duty as a Citizen.

A reception followed at which the membership were given an opportunity to meet Admiral Melville and Sir William White and dancing and refreshments concluded the evening.

Friday Morning, June 3

At the final session of the convention, held at ten o'clock Friday morning, four papers on Power Transmission were presented. The first, Ball-Bearing Lineshaft Hangers, by Henry Hess of Philadelphia, gave in detail the actual and relative first cost of a lineshaft installation, with plain bearings and ball bearings, and showed the saving secured by the latter. It was discussed by F. B. Gilbreth, H. J. Smith, F. W. Dean, J. S. Bancroft, C. J. Jackson, Harrington Emerson and G. N. Van Derhoef.

Following this, Prof. Wm. T. Magruder of Columbus, O., presented his paper on Experimental Analysis of a Friction Clutch Coupling, giving the results of five lines of investigation. It was discussed by H. J. Smith, who illustrated his discussion with lantern slides, G. N. Van Derhoef, E. P. Haines and Oberlin Smith.

A paper by Prof. C. M. Garland of Urbana, Ill., on An Improved Absorption Dynamometer, was next presented, describing a type of eddy-current dynamometer, adapted for the absorption of power given out by motors under test, with an enumeration of the conditions that should be fulfilled. Prof. C. M. Allen discussed the paper.

The fourth and last paper was by S. H. Weaver of Schenectady, N. Y., on Critical Speed Calculation, treating of the properties of equations of vibration, with curves showing the amplitude of vibrations at different speeds for various shaft loadings, spans and bearing supports. Henry Hess, S. A. Moss and M. Nusim discussed the paper.

Following the professional session, Jesse M. Smith, Past-President, presented the following resolution of thanks, which was unanimously adopted.

Resolution of Thanks

Whereas The American Society of Mechanical Engineers at the Semi-Annual Meeting held at Atlantic City in May-June 1910, desires to express its appreciation to those who have so bountifully provided for the entertainment of the visiting members,

Be It Resolved that the Secretary be instructed to extend the thanks of the Society and express the appreciation of its members and guests, to the local committees for their untiring efforts in providing for the comfort and pleasure of the visiting members.

Entertainment

During the entire convention roller chairs for the boardwalk were made available to the membership and admission furnished to the Golf Course at Pleasantville and to the entertainments on the piers.

The Ladies' Committee, with headquarters at the Marlborough-Blenheim, under the Chairmanship of Mrs. Charles Day, contributed in every possible way to the pleasure of the visiting ladies throughout the meetings, and tea was served at headquarters on Tuesday, Wednesday and Thursday afternoons, to which the members were also invited.

MEETING OF THE COUNCIL

The annual spring meeting of the Council was called to order at 5 p.m., Tuesday, May 31, 1910, in the director's room of the Marlborough-Blenheim, Atlantic City, N. J.

There were present, George Westinghouse, in the Chair, Charles Whiting Baker, J. Sellers Bancroft, R. C. Carpenter, H. L. Gantt, E. D. Meier, I. E. Moultrop, H. G. Reist, Jesse M. Smith, Ambrose Swasey, W. J. Sando, F. W. Taylor, W. R. Warner, W. H. Wiley and the Secretary.

The minutes of the meeting of April 12 were read and approved.

The following deaths were reported: James H. Blessing, W. W. Churchill, R. W. Emerson, H. S. Haskins, Walter C. Kerr, F. J. Plummer, I. I. Redwood, J. H. Bloomberg, M. W. Parsons, Jas. H. Bridge, E. P. Sparrow. The resignations of Asa S. Cook, W. W. Kuntz, A. S. Wardell, E. B. Arnold, Lewis Searing, Harry E. Paine, Chas. Wachalofsky, Jr., E. G. Rust and H. A. Dunn were accepted.

Voted To adopt the report of the Executive Committee with regard to the conduct of meetings of the Society with the amendment "subject to the approval of the Council."

Voted To refer the report of the Committee on Licensing Engineers, Chas. Whiting Baker, Chairman, to the Committee on Public Relations to be appointed.

The Secretary reported that the invitation of the Engineering Standards Committee of Great Britain for a conference on standards for screw threads had been declined, as there would not be sufficient opportunity in connection with the other meetings of the institution of Mechanical Engineers to hold such conferences.

Voted To refer the report of the Special Committee on Balloting to a joint meeting of that committee with the Committee on Constitution and By-Laws.

Voted: To accept and adopt the report of the Special Committee on Identification of Power House Piping by Colors, H. G. Stott, Chairman, and to reappoint the same Committee, requesting them to make a report to the Council.

Voted: To adopt the amendment to B 37, as follows:

B 37 The Annual Meeting shall begin in the City of New York on the first Tuesday in December and continue from day to day as the Council may direct.

The Annual Business Meeting of the Society shall be held on the Wednesday following the first Tuesday of December.

The Semi-Annual Meeting shall be held in such a place and begin on such a day as the Council may direct, and continue from day to day.

The Semi-Annual Business Meeting of the Society shall be held immediately preceding the first professional session of the Semi-Annual Meeting.

Professional meetings of the Society for the reading and discussion of papers and for topical discussions may be held at such times and places as the Council may direct.

Announcements of all meetings of the Society shall be published in The Journal.

A notice of each Annual and Semi-Annual Meeting and each Annual and Semi-Annual Business Meeting of the Society shall be mailed by the Secretary to each member in each grade not less than 30 days before the date of that meeting and at least 30 days before each Special Business Meeting.

The Secretary reported that the Ballot on the amendment to the Constitution had been accepted by the Membership, thus adding the Public Relations Committee to the Standing Committees of the Society.

The Secretary reported the appointment of Carl Albert Johnson and Prof. T. G. D. Mack as Honorary Vice-Presidents to represent the Society at the opening of the Forest Products Laboratory at the University of Wisconsin.

On motion meeting adjourned.

STUDENT BRANCHES

COLUMBIA UNIVERSITY

On May 13, the following officers of the Student Branch at Columbia University were elected for the ensuing year: F. T. Lacy, president; W. H. Sellew, vice-president; J. L. Haynes, secretary; B. Rogowski, treasurer. A talk was given by Mr. Averill, managing editor of the Electric Railroad Journal, and lieutenant of the First Batallion, N.M. N. Y., on the engineering aspects of the batallion.

CORNELL UNIVERSITY

At a joint meeting of the Student Branch of The American Society of Mechanical Engineers and the Cornell Section of the American Institute of Electrical Engineers, on April 25, Wm. Macomber, of Buffalo, N. Y., gave an address on Patent Law. A social meeting followed, at which Prof. D. S. Kimball, Mem. Am. Soc. M. E., gave an illustrated talk on California.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

At a meeting of the Student Branch of the Massachusetts Institute of Technology, held May 13, C. H. Bigelow, Mem. Am. Soc. M. E., read an interesting paper on Inspection, which dealt particularly with reinforced-concrete and brick construction and their foundations. The paper was illustrated by lantern slides.

PENNSYLVANIA STATE COLLEGE

The last regular meeting for the year was held May 18, when the following officers were elected for the year 1910-1911: W. E. Heibel, president; J. A. Minnich, vice-president; G. M. Forker, secretary; J. A. Hassler, treasurer. Addresses were made by Charles E. Downton, on Modern Manufacturing Methods; by Prof. A. J. Wood, Mem. Am. Soc. M. E., on The Determination of the Specific Heat of Ammonia; by Prof. Hugo Diemer, Mem. Am. Soc. M. E., on The Human

Side of Engineering; and by I. H. Yoder (1910) and R. H. Mobley (1910), on the Interurban Railway proposition, from business and technical points of view.

PURDUE UNIVERSITY

At the meeting of the Student Branch of Purdue University, held May 4, 1910, Prof. M. J. Golden, Mem. Am. Soc. M. E., gave a talk on The Design and Construction of the New Shops of Purdue University.

STANFORD UNIVERSITY

On May 4 the following officers were elected by the Stanford University Student Branch for the year 1910–1911: J. B. Bubb, chairman; N. M. Day, vice-chairman; H. H. Blee, secretary-treasurer. A number of new members were elected. The business of the meeting was followed by a talk on Machine Shops, by E. P. Lesley, which was illustrated with lantern slides.

STEVENS INSTITUTE OF TECHNOLOGY

On May 10, 1910, Dr. John A. Brashear, Mem. Am. Soc. M. E., addressed the Stevens Engineering Society on The Contributions of Photography to our Knowledge of the Stellar Universe. The following officers were elected for the ensuing year: W. G. H. Brehmer, president; T. A. Horton, vice-president; J. G. Bainbridge, secretary; A. R. Lawrence, treasurer.

UNIVERSITY OF CINCINNATI

At the regular meeting of the University of Cincinnati Student Branch on May 20, the following officers were elected for the year 1910-1911: H. B. Cook, president; H. M. Stewart, vice-president; C. J. Malone, secretary-treasurer.

At the meeting on June 17 the members made an inspection trip to the plant of the Union Gas and Electric Company.

UNIVERSITY OF MAINE

At the meeting of the Maine Affiliated Student Branch on May 4, two papers were read, one by A. C. Hammond on The Mono-Rail Car, and the other by W. W. Hatch on Manual Training in the Secondary Schools.

UNIVERSITY OF MISSOURI

The Club of Mechanical Engineers of the University of Missouri was addressed on May 2, by J. R. Wharton on Refrigeration Insulation. On May 16, a paper was read before the meeting on Expert Testing of Locomotives, by Prof. H. Wade Hibbard, Mem. Am. Soc. M. E.

UNIVERSITY OF NEBRASKA

Prof. C. R. Richards, Mem. Am. Soc. M. E. delivered a lecture before the University of Nebraska Student Branch at its meeting of May 10, on Some Points in the Design of the Steam Turbine.

WISCONSIN UNIVERSITY

R. N. Trane (1910) gave a talk on An Electric Gas Meter before the meeting of the Student Branch of Wisconsin University, on May 5, in which he described the construction and operation of the Thomas gas meter. At the close, Prof. C. C. Thomas, Mem. Am. Soc. M. E., explained some of the finer details of the apparatus and the latest improvements on it, showing how the instrument is calibrated so that the reading of the watt-meter multiplied by a constant gave directly the quantity of gas passing through the meter.

NECROLOGY

WALTER CRAIG KERR

Walter Craig Kerr was a notable example of a type of engineering practitioner peculiar to the United States, the producer of great engineering achievements, who is a constructor as well as a consulting engineer. Such an engineer draws up and submits to his clients his own specifications for the work to be done for the latter; and then as supervisor or general contractor undertakes to carry these out under his own direction, his compensation coming to him not in the form of a consultant's fee, but of the profits from the financial undertaking. This system has been called the American system as distinguished from the British or European.

Mr. Kerr was born at St. Peter, Minn., on November 6, 1856. He was graduated from Cornell University in 1879 with the degree of B. M. E., and remained at Cornell for an interval of three years, as instructor and later assistant professor in mathematics. In 1882 he became a salesman and installing engineer for the Westinghouse Machine Company, designing the general installations for his company. In one year he was made manager of their eastern office. Through his realization of the common advantage to producer and consumer if the former can both supply the material and properly erect it, a company was formed in 1884 of which Herman Westinghouse, Mem.Am.Soc.M.E., William L. Church, Mem.Am.Soc.M.E., and W. C. Kerr were the nucleus. In this company and with the work it soon found for itself to do, Mr. Kerr was a forceful personality; and his faculty for organization and his energy as an officer have been large factors in the increase of its scope and the magnitude of its undertakings. He was vice-president at the start, and as the result of later changes in the personnel, he was president of the company at the time of his death. He was at one time vice-president of the Westinghouse Machine Company and was also a director of the Electric Properties Company at his death. New York City merchants recently elected him a vice-president of the Merchants' Association. He became a member of The American Society of Mechanical Engineers in 1886 and was active on its committees whenever asked to serve and full of helpful suggestions at many times. He was a member also of

the Engineers Club, the American Institute of Electrical Engineers, the Canadian Civil Engineers and other business and social organizations. He was an enthusiastic yachtsman at his home on Staten Island and effective governor of the local club. He died at Rochester, Minn., May 8, 1910.

It results of course from Mr. Kerr's advocacy of the constructive principle above referred to, that coöperation of engineer and contractor is to be preferred to an antagonism between them, that his monuments of achievement are those of his company rather than of any individual. This is both a loss and a gain, or perhaps is the algebraic sum of the two. By embodying their own designs in a materially existing structure, the name of the designs is not lost, as is so sure to be the case when they did not also construct. The grandeur of the structure as a material fact overshadows the mental achievement of the great concept, and the fact that it was the work of many obliterates the significance of the work of the organizing mind. But the work of the company has covered the construction of interurban electric lines in Michigan, Ohio, Missouri and New York states; power plant design and installation using both steam and water power for railways, lighting plants and producing factories. This firm electrified the Long Island Railway among others. Much of the power and hydro-electric plant for Cornell University was put in by their company, as Mr. Kerr had served as Trustee for the University for many years and was active in bringing Prof. R. H. Thurston to the Directorship of Sibley College in 1885.

But the most considerable single undertakings with which Mr. Kerr was identified will always be the engineering of the great Southern Terminal Station in Boston, Mass., and the new great uptown terminal of the Pennsylvania Railway at the end of its tunnels under the Hudson river, and the connecting subways. These have been splendid examples of the effective coöperation of the architects and engineers of the railways as owners and beneficiaries, and the consulting-constructing parties who were grouped together under Mr. Kerr's leadership. The Pennsylvania Terminal at 33d Street and 7th Avenue was visited by the Society in a body under the guidance of Mr. Kerr and Mr. Gibbs, by their invitation, at the time of the Annual Meeting in New York in 1909. Mr. Kerr was persuaded to present an account of the Boston Terminal at the Annual Meeting of the Society in December 1899[1] which is a model of a clear and concise presentation of a large topic.

[1]Transactions, vol. 21, p. 451, No. 845.

JAMES WELDON BRIDGE

James Weldon Bridge, an associate member of the Society, was born at Atlanta, Ga., March 24, 1873, and educated in the public schools of Atlanta, receiving in 1892 the degree of B.S. of M.E. at the Georgia School of Technology.

His early shop experience was with the Atlanta Consolidated Street Railway Company from 1894 to 1898, at which time he entered the drawing room of the Atlanta Railway and Power Company, becoming general foreman of shops in 1900. In 1902 he became superintendent of the manganese mines, Georgia Iron and Coal Company, and afterwards held various positions of importance with city and interurban railway companies. At the time of his death, December 20, 1909, he had just taken up the work of general manager of the Pittsburg, Monongahela & Washington Street Railway Company, stationed at Monongahela, Pa.

Mr. Bridge was a member of the Sigma Alpha Epsilon fraternity, and entered this Society in 1905.

FRANCIS JOHN PLUMMER

Francis John Plummer of Norwich, Conn., died April 5, 1910, and was buried at Worcester, Mass.

Mr. Plummer was born at Lancaster, Mass., February 29, 1840. He was apprenticed from 1857 to 1860 to Ball & Williams of Worcester, Mass., and continued with them as journeyman machinist until 1863, subsequently becoming foreman and superintendent for Ball & Williams and R. Ball & Company, where he remained until 1868. He then entered the employ of the S. A. Woods Machine Company, of Boston, leaving them for a brief connection as partner with the firm of E. C. Taintor & Company, of Philadelphia. Returning to the Boston firm, he took charge of the works and acted as superintendent from 1878 to 1885. His next connection was with Goodell & Waters of Philadelphia, also builders of wood-working machinery, where he held for five years the position of designer of planing-mill machinery. In 1890 he became associated with C. B. Rogers & Company of Norwich, Conn., of which he was superintendent and manager until 1907, when ill health compelled his resignation. His work was almost exclusively the design and manufacture of wood-working machinery, especially planing, molding and sawing machines for general building and car work. Many of his inven-

tions are now extensively manufactured by the American Wood-Working Machinery Company.

Mr. Plummer was a member of Sedgwick Post, G. A. R., having enlisted from Worcester with the Third Batallion Rifles in April 1861; and of several masonic orders. He entered this Society in 1891.

ERNEST PACKARD SPARROW

Ernest Packard Sparrow, who died in Dorchester, Mass., on April 18, 1910, was born at Portland, Me., September 17, 1857, and received his early education from the Westbrook Seminary. In 1880 he was graduated from the Worcester Polytechnic Institute with the degree of B.S.

Mr. Sparrow's first shop experience was with the Indurated Fibre Company, Gorham, Mass. He was subsequently associated with the Fitchburg Steam Engine, the Mather Electric Light, the Thompson-Houston Electric Light, the Jarvis Engineering, the E. P. Allis, the Boston Rubber Shoe, and the New Brunswick Rubber companies. For the past few years he had been associated with the B. F. Sturtevant Company of Hyde Park, Mass., where he was engaged on special engineering work.

Besides being a member of this Society, Mr. Sparrow was affiliated with several benevolent orders and organizations.

ILTYD ISAAC REDWOOD

Iltyd Isaac Redwood was born in London, December 16, 1863. He was educated at private schools, attending courses in elementary mechanics and drawing, afterwards supplementing them by evening study.

He began his career as a chemist in 1879 when for two years he acted as assistant to his father, Dr. Theophilus Redwood of the Pharmaceutical Association of Great Britain. In 1882 he became assistant chemist in the laboratory of Young's Paraffin Light and Mineral Oil Company, Ltd., in Scotland, and in 1887 entered the employ of the Queen's County works of the Standard Oil Company, where he became successively chemist, foreman of various departments, assistant superintendent in charge of construction work, and draftsman. Since 1897 he had been technical manager and expert adviser of the English works of Borax Consolidated, Ltd., manufacturers of borax and allied products.

Mr. Redwood was a member of the Society of Chemical Industry, the Royal Society of Arts, and the Aëronautical Society of Great Britain. He entered this Society as an associate in 1890 and was made a full member in 1903. He was the author of several works, namely, Ammonia Refrigeration; Mineral Oils and their By-Products; Lubricants, Oils and Greases; and was a recognized authority on chemical engineering.

WILLIAM NELSON PARSONS

William Nelson Parsons was born at Northampton, Mass., February 15, 1869, and received his technical training as a special student in mechanical engineering at Cornell University.

Mr. Parsons served his apprenticeship as a machinist with Charles C. Herrick of Northampton and later entered the employ of the Deane Steam Pump Company, Holyoke, Mass., and the Stanley Electric Manufacturing Company, Pittsfield, Mass. In 1900 he was employed in the drawing room of the Taft Pierce Company of Woonsocket, R. I., and at various times subsequently with the Goulds Company of Seneca Falls, N. Y., the Royal Electric Company of Montreal and the Steamobile Company of America. At the time of his death, April 24, 1910, he was chief draftsman for the Buffalo Bolt Company of North Tonawanda, N. Y.

JONAS HENRY BLOOMBERG

Jonas Henry Bloomberg was born in New York City, February 2, 1870. He was educated in the public schools and later at the College of the City of New York, leaving there in 1900 to go to Mexico where he devoted himself with great success to sugar house machinery. He built and designed most of the modern sugar houses and distilleries there, the more important ones being at the Rio Vista Plantation, the Almonte Plantation and the La Crosse Plantation. At the time of his death, April 27, 1910, he was consulting engineer of the Rio Tamasopo Sugar Company of Tamasopo, S. L. P.

Mr. Bloomberg was a member of the National Geographical Society of Washington, D. C., as well as a member of this Society.

THE ENGINEER'S DUTY AS A CITIZEN

By Rear-Admiral Geo. W. Melville, U. S. N., Ret.

Honorary Member of the Society

Doubtless everyone present has read Macaulay's famous chapter, in his History of England, which describes the conditions obtaining in 1685. This chapter is one of the most wonderful descriptions in all literature, giving as it does the details of every feature of the life of that time, some 200 years ago. I refer to this account because I want you to contrast it with the conditions of today, to which we are so accustomed that it requires some effort to remember that the comfort and conveniences of the poor man of today are beyond the wildest dreams of the wealthiest men of the period described by Macaulay. At that time there were no sidewalks and the streets were unlighted; the highways became bogs in rainy weather, and highway robbery was almost a recognized profession; sanitation and sewerage were unknown, and refuse heaps accumulated under the windows of the great and the wealthy; it was dangerous to go out alone at night; and it was still legal to hang the unfortunate who stole a loaf of bread.

2 Macaulay remarks in one place that at such fashionable watering places as Bath, the nobility had to put up with accomodations at which their servants in the year 1850, in which he was writing, would turn up their noses.

3 Now when we compare the two periods and remember that there is hardly a branch of human activity in which there has not been the greatest improvement, we are naturally led to ask to whom is the improvement due.

4 In all fairness, we should doubtless have to say that most of the professions have had a part in the amelioration of conditions, although the student of history remembers with regret how the great lawyers opposed the remission of the death penalty for what we would now consider minor offenses.

5 Physicians are undoubtedly entitled to much credit for advances in medicine, surgery, sanitation and hygiene, and we might

Address given at the Atlantic City Meeting of The American Society of Mechanical Engineers, 29 West 39th Street, New York, July, 1910. All papers are subject to revision.

go on and give credit to others. It seems to me, however, that when some future Macaulay describes the condition of the United States at the beginning of the twentieth century and attempts to award the credit for the existing comforts and conveniences, the major part must be given to the profession of engineering. Within 100 years after the time described by Macaulay, Watt had so far perfected the steam engine as to bring about the beginnings of the factory system, making possible the low cost of clothing and of articles of manufacture of every kind. In a century the steamboat and the railroad had come into being. Then we have gas for illumination and the telegraph for rapid communication, and so on down the line to the present day with its electric light, electric railroad and telephone, every one due to the engineer.

6 Added to the superior facilities of communication by railroad and steamer came mechanical refrigeration, which enables the densely populated countries of the old world to be supplied with meats from the great plains of the new, and these superior means of transportation have provided the rapid movement of food products so that the whole world contributes to the delicacies of our table, no matter where we are.

7 The contrast between the conditions of the great cities of the period described by Macaulay wi h those of today is startling. Cities were without the conveniences which a country town of moderate size would now consider absolute necessities. The systems of water distribution, sewerage, street paving, etc., are all the work of the engineer, and filtration plants obviously are engineering works, even if we consider their inception to be due to the medical men.

8 Perhaps you ask why I should go into these details which are common knowledge, when their mention can give little additional information. My reason is that I want to emphasize the facts as a basis for the discussion of the question: What does the engineer owe to society when society owes so much to the engineer.

9 In the early history of the race, when war was the almost constant condition it was inevitable that the great warrior should become the leader and ruler of the people. As time went on, the engineer developed, as we know from the wonderful works of antiquity like the great aqueducts, the bridges, tunnels and roads; but, from the past, had come the tradition lodging leadership in the warrior caste, where it remained for many centuries, and, indeed, has still a tendency to remain in monarchical countries.

10 During the last century, wars have been less frequent, and,

due to the engineer, commerce has become so prominent that while the hereditary nobility still linger on the scene, their titles have become almost meaningless. This was particularly noticeable when one of the English dukes served in the quartermaster's department during the Boer war in a subordinate capacity, and still more so in the war between Russia and Japan, when only one Russian general was a member of the nobility.

11 I think you will see the point to which I am leading; namely, that in this "age of the engineer," he should not rest content simply with doing the work which makes for our comfort and happiness, at the command of others, men who are lawyers or simply business men, but that the engineer himself should take a vital and directing part in the administration of affairs. I know the objection that an engineer's professional work is so engrossing and exacting that he cannot become a politician in the sense that a politician is a man who gives all his time to pulling wires and filling offices. This is doubtless true, but where it is a matter of self-interest, the engineer, like other men, can find time for this extra work.

12 We Americans are fond of claiming that we have the greatest country and the most free and best government in the world. That government, however, for its efficiency and integrity depends upon us as citizens, and it ought to be a matter of the greatest pride to every American to do his part, so far as lies in him, to make the country and its government better and happier every year.

13 In view of the enormously important part which the engineer plays in the life of today, it is incumbent upon him, more than upon most other men, to take a vital interest in the work of government and to lend his trained ability and judgment to its perfection. I do not mean of course that the engineer should do routine professional work for the government without compensation, but that in the discussion of public improvements and the administration of governmental departments, he should take an active public stand to influence and guide the non-expert part of the population.

14 It is notorious that enormous amounts of money have been squandered on great public works because they were undertaken in a way which every engineer knew must be inefficient and uneconomical. If all of us as engineers had a keen sense of our duty in this respect, and would properly utilize our experience and ability through the daily press, the magazines and the reviews by public discussion and in the daily intercourse of life, as well as by impressing the truth upon our representatives in municipal and national affairs, I believe we would accomplish an immense amount of good.

15 It will be understood, I am sure, that in this I refer almost entirely to the relations of engineers to society in general, and not to other professional men. For many years engineers have been most generous in making public to their technical brethren the results of their experience, and our own Proceedings are full of instances. It would be impossible to name more than a few, but perhaps the most notable case was that of Past-President Taylor in the publication of the results of his life work of research on the Art of Cutting Metals.

16 A problem of foremost importance at the present time is the management of labor to secure efficient work and satisfied men. It is probable that the direction of more than 90 per cent of the skilled labor is in the hands of engineers. Most emphatically is this a case where engineers owe a great duty to society. It is, therefore, an especial pleasure to recognize that some of our own members have played a foremost part in the best work that has been done in devising plans for compensating labor which will stimulate the men to their best efforts and reward them adequately. The names of Halsey, Taylor, Gantt and Emerson will at once occur to you

17 It would be inappropriate in this brief address to attempt a detailed discussion of the labor problem, but I feel that I shall voice the sentiment of every one present when I say that the effort of every patriotic American should be exerted to maintain absolute freedom of contract in labor matters as in all others. Just as we are opposed to monopoly by capital, so we are to the same thing by labor.

18 No reasonable man objects to labor organizations, as such. They have undoubtedly been the cause of much benefit to the men. The danger with them, as with political organizations, is the formation of a machine which utilizes the organization solely for the selfish interests of the members of the machine. There can be no doubt whatever that many strikes are against the real wishes of a majority of the men, who are overborne by the machine and its adherents; and it is also true that the net result of nearly all strikes is an actual loss to the men. The problem is an exceedingly difficult one and requires the greatest wisdom, patience and tact for its complete solution; if, indeed, taking human nature as it is, we can ever hope for its removal from the list of worries of the manager of great enterprises.

19 Many questions prominently before the public are peculiarly such as require engineering knowledge for their proper understanding and regulation. The word trust has come to have such a sinister meaning that it is only necessary to fasten it upon an enterprise to render it criminal in the popular estimation. We have recently heard a great deal about the so-called Water Power Trust, the charge being

that all the available power sites were being grabbed so as to subject our citizens at some future time to the payment of tribute for electric power derived from them. I am not concerned, at the moment, with a discussion of monopolies, which we all deprecate, but to point out that engineers know these water powers cannot be made available except by the expenditure of large sums of money. Indeed, it would be easy to point out the fortunes that have been lost in the attempted exploitation of these supposedly lucrative natural gifts. The general public is utterly misled by statements that these power sites are obtained for nothing, the idea being that the development is a matter of small expense. Here the engineer can do a work of real benefit by disseminating correct information.

20 Again, in the consideration of public service corporations, the engineer knows the cost of installation and operation, and so can discuss intelligently whether rates are fair or exorbitant, and whether capital represents real investment or water. These are problems of the greatest importance, and for their proper solution, the electorate needs training that can be given by no one else so well as by the engineer.

21 About a year ago, at our Washington meeting, I did what I could along this line by pointing out mistakes in connection with navy yard organization, and this illustrates very clearly what I am advocating for all engineers. Here was a great department of the Government for which the annual appropriation now exceeds one hundred millions of dollars. Its administration had fallen into the hands of a man who started to make changes in the entire administration which would have been ruinous to efficiency; and yet, hardly a voice was raised in opposition. I even heard of a case where one of our leading engineering journals refused to publish a criticism of this system submitted to them through a man whom they knew and esteemed most highly, but who stated that the author was so situated that he could not permit his name to be used. Not only would the magazine not print the article but they did not take enough interest in this most important subject to study it for themselves and comment upon it.

22 I do not mean to imply that engineers never show public spirit in such ways as I have suggested: there are too many instances to the contrary. Our own Society and others which have taken part in the movement for conservation of our natural resources have set a good example, and other cases could be cited where individual engineers have shown commendable enthusiasm. These, however, are mostly cases of unusual importance and relatively infrequent. What I am

pleading for is a habit of mind that will cause engineers to take an active part in all public questions, great or small, where their knowledge and experience will enable them to contribute to the common good.

23 The movement which has been set on foot by Congress to establish a Bureau of Mines suggests an opportunity for the engineer to take an active part in public affairs. I question whether this idea might not be developed a little further by providing for a department with a Cabinet officer at the head, to be called the Department of Mines and Manufactures, with the scope implied by the title.[1]

24 When we think of the enormous values represented by the industries which would come within the purview of such a department, it seems only reasonable that they should be under the care of a Cabinet officer. If we are told that there is already the Bureau of Corporations, I would point out that the object of this proposed new department is quite different from that of the existing bureau which thus far, in the estimation of many, has done little or nothing to advance the interests of manufacturing, but has, in their opinion, disclosed a spirit which is almost inimical. The department that I have in mind would aim to stimulate improvement and progress in manufactures and industries generally, in somewhat the same way that the Department of Agriculture has done for the farmers.

25 We have often heard engineers complain that the profession did not receive due praise and credit for its splendid work. This is true enough, but is the reason not very largely because the engineer hitherto has been content to do the work and then fade into the background, leaving the talking and the management to the lawyer and the politician? With the advance of technical education, engineers are more and more becoming the high officials of our large corporations. It is to these men, whose talents and trained ability have made them the leaders in manufacturing and in business, that the country has the right to look for leaders in the affairs of government, and not until the engineer of all grades has done his part towards the promotion of the highest efficiency of the Government can he truly say that he is, in the fullest sense of the term, a good citizen of the Republic.

[1]This address was prepared more than a month ago, and since that time the bill in Congress referred to above has become a law. The newspapers have published an item that consideration was being given to the formation of a Department of Public Works. This is along the same general line as my suggestion above for a Cabinet officer to head a Department of Mines and Manufactures.

THE ELECTRIFICATION OF RAILWAYS

AN IMPERATIVE NEED FOR THE SELECTION OF A SYSTEM FOR UNIVERSAL USE

By George Westinghouse, Pittsburg, Pa.
President of the Society

As an illustration of the wonders of the laws of nature, few inventions or discoveries with which we are familiar can excel the static transformer of the electrical energy of alternating currents of high voltage into the equivalent energy at a lower voltage.

To have discovered how to make an inert mass of metal capable of transforming alternating currents of 100,000 *volts into currents of any required lower voltage with a loss of only a trifle of the energy so transformed, would have been to achieve enduring fame. The facts divide this honor among a few, the beneficiaries will be tens of millions.*

1 In less than twenty-five years a new industrial and economic situation has been created by the development of apparatus to generate, distribute and utilize electricity. Not less than two thousand million dollars have been invested in plants to manufacture apparatus, in power houses to generate electricity, in lines of copper wire to transmit this mysterious energy, in construction of railways and their equipment, and in the manufacture of products unknown before the advent of electricity.

2 Large sums have already been spent in the electrification of portions of standard steam railways in England, continental Europe and America, and there is now available a fund of information of inestimable value to guide those charged with the selection of an electrical system for railway operations.

3 The president of our brother Institution of Mechanical Engineers, Mr. Aspinall, in his presidential address delivered April 23, 1909, placed the railway world under deep obligation for most valuable information upon the electrical equipment and operation of trains of the Lancashire & Yorkshire Railway, of which he is the

The American Society of Mechanical Engineers, 29 West 39th Street, New York. July 1910. All papers are subject to revision.

worthy and skillful general manager. His observations on the effects of low center of gravity and heavy inflexible motor trucks upon the permanent way are especially valuable in that they direct attention to costs which at first were not considered with sufficient care.

4 Believing unreservedly that the increased capacity of a railway and its stations, the economies of operation, and other advantages will bring about gradually the systematic electrification of steam railways, my wish is that the progress of the art may not be hampered and such electrification of our main lines delayed or rendered unprofitable by mistakes which experience, judgment and foresight may enable us to avoid.

5 It is my intention in this paper to direct attention to the necessity for the very early selection of a comprehensive electrical system embracing fundamental standards of construction which must be accepted by all railway companies in order to insure a continuance of that interchange of traffic which, through force of circumstances has become practically universal, to the great advantage of transportation companies and of the public.

6 Having been identified with railway operations for over forty years, and with the development of the electrical industry for twenty-five years, I feel that the time is ripe for such a selection unless we are willing to regard with complacency the extension of the existing diversified systems and the creation of conditions which will prevent the general use of the most practical methods of operation.

7 Indeed, the tendency seems to be toward diversity rather than unity, since different types of third-rail construction have been adopted, even for the several continuous-current systems in and about New York City, which renders interchange of cars or locomotives difficult or impossible.

8 Although the facts clearly show the contrary, there exists a popular impression that the electrification of railways is a simple matter, and that it requires only decisions by boards of directors to insure the immediate substitution of the electric for the steam locomotive.

9 The great difficulty in the electrification of standard railways is no longer the engineering problem of developing a locomotive and an electrical system which will operate trains, but it is a broad question of financial and general policy of far-reaching scope, considering the future electrification of railways in general as distinguished from isolated cases of limited extent, and requiring a combination of the highest engineering and commercial skill.

GAGE OF TRACK AND INTERCHANGE OF TRAFFIC.

10 In the first days of railway operation, there was probably no idea of an interchange of traffic involving the use of the engines and cars of one railway upon the lines of another railway. It then made no difference whether the gage of track were 4 ft. 8½ in., the one ultimately selected, or one of a greater or lesser width by a few inches. The gage selected by Stephenson was a practical one, fortunately, since it has become almost universal, with a strong probability that it will one day be absolutely so.

11 Stephenson's successful demonstrations prompted experimenters in other countries, who naturally failed to appreciate the inconvenience and losses which were to follow the adoption of different gages. The general tendency to extend along the line of least resistance, made it inevitable that a railway once started upon a certain gage would make no change, and thus there were developed systems of railways with different gages of track. In the early days too, there were those who believed it to their advantage to establish a gage of track that would absolutely prevent the cars and engines of a connecting line from coming upon their line.

12 In some cases in the United States the difference in gage was, fortunately as it afterwards proved, only 1½ in., a difference successfully met, for the purpose of interchange of traffic, by the adoption of broad-tread wheels and minor changes in the track construction. In other cases, the gages adopted were 5 ft., 5 ft. 6 in., and 6 ft., and in some of these cases the necessity for through passenger traffic led to the changing of car trucks, at certain important places, so that passengers could be transported through to their destination without changing cars.

13 In 1878 there were in the United States eleven different gages of railroad tracks in addition to the standard gage of 4 ft. 8½ in.

14 The absolute necessity for uniformity of gage of tracks both in the United States and Canada became so apparent that in due course all of the roads which had gages wider than 4 ft. 8½ in. changed to the present standard. Among the remarkable achievements of engineering was the change of the tracks of an entire system of railway of some hundreds of miles within twenty-four hours, this change having, however, required months of preparation. The losses entailed in the change of gage and of equipment have ever since been serious burdens to most of those railways, in that the costs were in most cases covered by capital charges.

15 It may be conceded that, so far as steam railway operation

is concerned, there are now no obstacles to the interchange of traffic in the broadest sense, except in the size of vehicles in certain countries where the cost of changing tunnels and bridges would be prohibitive.

REQUIREMENTS FOR INTERCHANGE OF TRAFFIC

16 With these preliminary remarks I feel certain you will agree that to insure interchange of traffic, the fundamental requirements, so far as operation by steam is concerned, with full regard for safety, speed and comfort, are very few in number and are covered by the following:

a A standard gage of track.
b A standard or interchangeable type of coupling for vehicles.
c A uniform interchangeable type of brake apparatus.
d Interchangeable heating apparatus.
e A uniform system of train signals.

The additional fundamental requirements for electrically operated railways are:

f A supply of electricity of uniform quality as to voltage and periodicity.
g Conductors to convey this electricity so uniformly located with reference to the rails that, without change of any kind, an electrically fitted locomotive or car of any company can collect its supply of current when upon the lines of other companies.
h Uniform apparatus for control of electric supply whereby two or more electrically fitted locomotives or cars from different lines can be operated together from one locomotive or car.

17 Outside of economy in capital expenditure, and economy and convenience in operation by steam or electricity, it matters not whether each locomotive and car and the apparatus upon them differ from every other locomotive and car in size or details of construction, so long as the constructions are operative and the materials employed are used within safe limits.

DEVELOPMENT OF ALTERNATING-CURRENT APPARATUS

18 Having acquired a considerable experience in the introduction upon railways of the compressed air brakes and in the development of automatic electro-pneumatic signals, I was led in 1885, because of its general analogy to operations with which I was familiar, to interest myself in the American patents of Gaulard and Gibbs (a Frenchman and an Englishman), covering a system of electrical distribution by means of alternating currents, with static trans-

formers to reduce these currents from the high voltage necessary for economical transmission of electrical energy to the lower voltages required for the operation of incandescent lamps and other purposes.

19 No inventions ever met with greater opposition in their commercial development than those relating to the generation, distribution and utilization of alternating currents, and it is a matter of record that the opponents of those interested in developing the alternating system even sought, through public meetings and the appointment of commissions, and by various extraordinary means, to influence and prejudice public opinion.

20 Realizing the limitations of the continuous or direct-current system, I became thoroughly convinced that the extended distribution of electricity for industrial purposes could be secured only by the generation of alternating currents of high voltage and their conversion by static transformers into currents of various voltages. Notwithstanding, therefore, the frank disbelief in its practical value by eminent scientific authorities, among them the late Lord Kelvin, I entered actively into the development of the alternating-current system of generation and distribution of electricity which is now almost universally accepted as the ideal.

21 By 1888 Nikola Tesla had demonstrated the practicability of his induction motors, Oliver B. Shallenberger had perfected his meter for measuring alternating currents, and it had been proved that a direct-current motor with laminated armature and fields could be operated either by alternating or by direct currents. I then became thoroughly imbued with the belief that further invention and discovery would in time make alternating-current apparatus practically universal for almost every purpose.

22 In 1892 two single-phase motors of about 10 h.p. were built by the Westinghouse company to determine the possibilities of using alternating current for traction work. These motors were designed for 2000 alternations per minute and about 200 volts. They were of the series type, with commutators, and had a relatively large number of poles. These were placed upon a car and tested on a short piece of track with very short curves and rather steep grades. There was a transformer on the car on which there were several taps and the voltage was varied by means of single-pole switches. It was considered at that time that the system would be ideal for locomotive work, but as there were no such projects in view, no large motors of this type were built. This development is referred to more at length in Appendix No. 5.

23 All so-called continuous- or direct-current generators really generate alternating currents and transform them by a commutator into continuous current, and such a machine will, by the application of collector rings upon its armature, deliver both alternating and continuous currents. The use of the commutator, however, so limits the voltage that large quantities of power cannot be generated for economical transmission by direct current. A machine so constructed can also receive alternating currents through the collector rings and transform them into direct current. As thus used the apparatus is called a rotary converter. When the supply of alternating current is at very high voltage, there has to be interposed between this supply and the rotary converter a static transformer to reduce the high primary voltage to the permissible lower voltage.

ELECTRICAL SYSTEMS FOR RAILWAYS

24 As soon as these qualities of the alternating current had been demonstrated, active minds were directed toward the development of apparatus to meet conditions constantly presenting themselves, among the most important problems being the electrification of railways. In the twenty years that have elapsed, three important electrical systems for the operation of railways have been put into practical operation, all using alternating current in whole, or in part. These systems are:

a The continuous- or direct-current system, usually spoken of as the "third-rail" system, which employs alternating current for transmitting power when the distance is considerable.

b The three-phase alternating-current system with two overhead trolley wires.

c The single-phase, alternating-current, high-tension system with a single overhead trolley wire.

25 In a notable case of the latter system, namely, that of the New York, New Haven & Hartford Railroad, the motors and controlling apparatus are arranged to utilize single-phase current from an overhead trolley wire at 11,000 volts, and also to be operated by current from the 650-volt third-rail system of the New York Central & Hudson River Railroad, thus making a demonstration of the wonderful flexibility of alternating-current apparatus.

26 The problem before the officials of the New Haven road was not merely the electrification of a division of a few miles of its track, rendered compulsory by legal requirements, but the selection of a system which would meet the needs of a great railway covering several

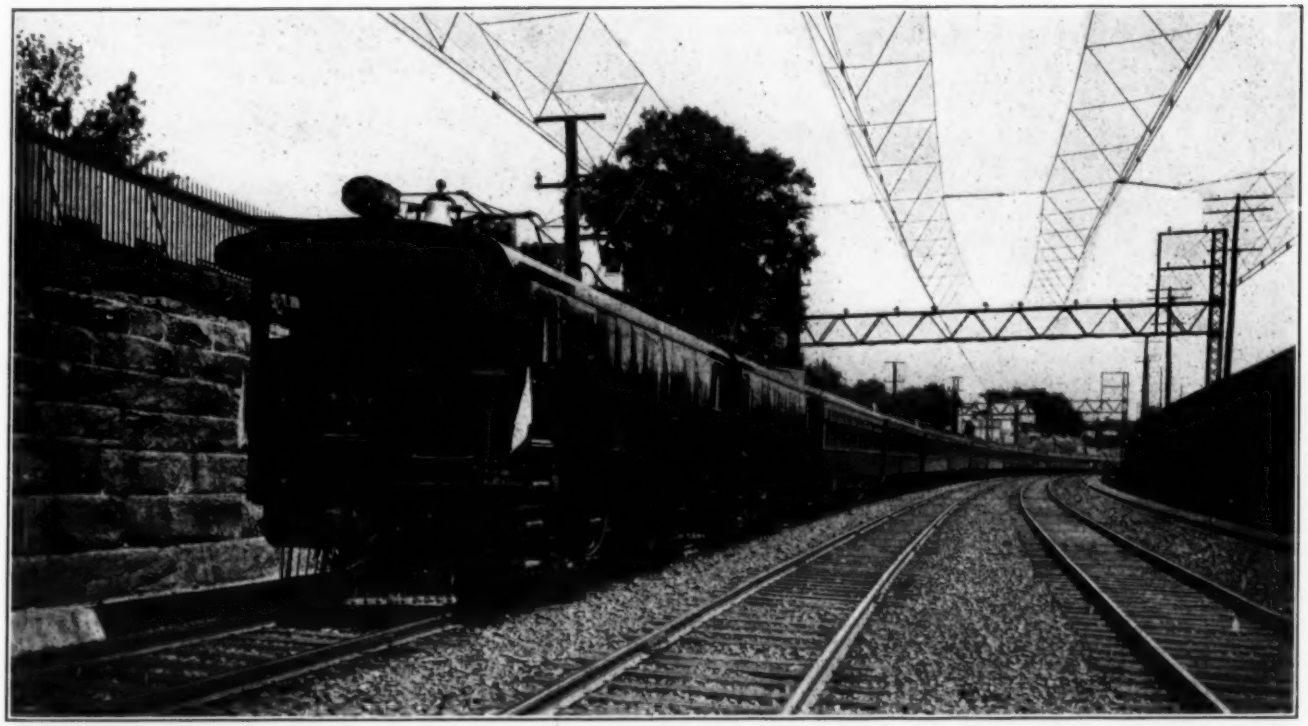


FIG. 1 SINGLE-PHASE ELECTRIFICATION OF THE NEW YORK, NEW HAVEN & HARTFORD RAILROAD

VIEW SHOWS TROLLEY WIRE SUPPORTED BY DOUBLE STEEL CATENARY CABLES SUSPENDED FROM LATTICE STEEL BRIDGES OVER THE FOUR TRACKS. THE ONLY ELECTRICAL CONSTRUCTION ON THE TRACK LEVEL IS THE SMALL COPPER BONDS CONNECTING THE RAILS.

states and having other congested centers of traffic which it might soon be desirable to electrify. In view of the fact that there had been no considerable demonstration of the single-phase system by actual use, and that the New Haven trains would be obliged to operate upon twelve miles of lines already equipped with the direct-current third-rail system, it must be conceded that the directors and management of the New York, New Haven & Hartford Railroad showed great courage and confidence in the judgment of their experts, and rendered to all other railroads a service of the highest character, when they selected the single-phase system for the electrification of the line mentioned.

27 As the single-phase method of operation is comparatively recent and is not so well known as the other systems, extended particulars are given in the appendices upon the extent of operation by this system, and upon the results attained in its use by the New York, New Haven & Hartford Railroad. The important experiences gained on that railroad furnish very important data to aid in the selection of a uniform system of electrical railway operation.

28 The paper[1] by Mr. George Gibbs, chief engineer of electric traction of the Pennsylvania Railroad, with reference to the electrifications by that company, submitted in June of this year to the International Railway Congress at Berne, Switzerland, gives most valuable particulars in regard to the practical electrical operation of a standard railway.

29 When the officials of the New York Central Railroad and those of the New York, New Haven & Hartford Railroad, who now have had an unusual experience, also present their available facts as to cost of installation, of maintenance and of operation, the railway world will have very complete information.

30 The results of the working of the three-phase system in Italy and Switzerland have been very prominently before the world for several years, and its successful use there has been a material factor in the development of confidence in electricity for the operation of railway trains. At the present time, the Italian Government is installing upon the Giovi line, which is a heavy-grade branch leading out of Genoa, a service for which twenty locomotives, rated at 2000 h.p., are now being constructed in Italy. The operation of this

[1] The report is entitled Electric Traction: Electric Traction on Large Railroads; Continuous Current; Alternating Current (Monophase or Polyphase); Comparative Net Cost. It appears in the Bulletin of the International Railway Congress Association, under Question 8, Report No. 2, by George Gibbs.

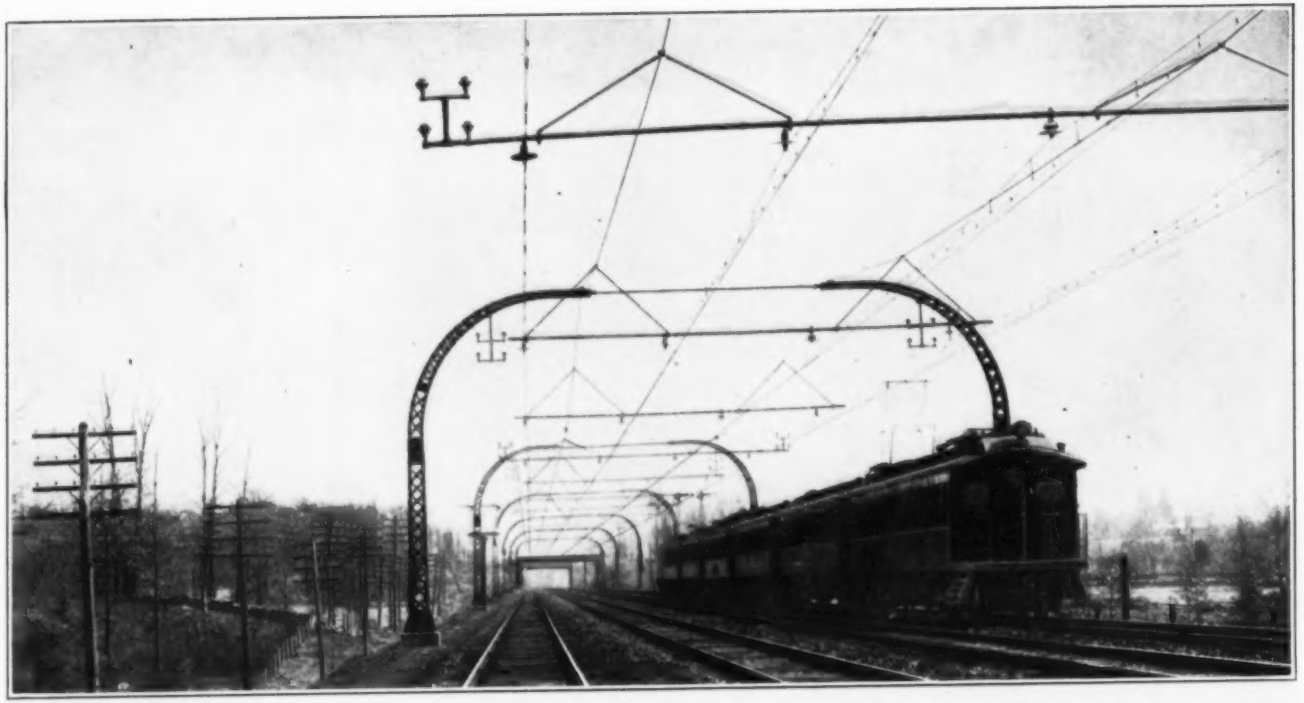


FIG. 2 MULTIPLE UNIT TRAIN FOR SUBURBAN SERVICE; OVERHEAD CONSTRUCTION OF NEW TYPE DEVELOPED BY THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD

much more extensive plant will afford additional valuable information as to the cost of installation and operation, and the advantages of the three-phase system.

31 The equipment of the power houses which generate the current is essentially similar in the three systems which I have enumerated; but the systems differ in the kind of motors and the auxiliary apparatus for controlling them, and in the methods and apparatus for transmitting the current from the power house to the locomotive or car.

RAILWAY MOTORS

32 Essential requisites in a railway motor are that it shall start its load and quickly accelerate it to the required speed, and that it shall operate continuously at any desired speed, or speeds. Railway conditions make desirable speeds varying from the slowest to the highest schedule speeds for regular operation, both for the movement of freight and passengers, and for making up time.

33 The steam locomotive, which is limited in power by its boiler capacity, is capable of continuous operation at any speed up to the maximum, but the maximum speed in a given case depends both upon the length of the train and the grade of the track. It automatically slows down when ascending a grade, so that the actual horsepower developed does not vary greatly at different speeds. The limitation of the capacity of the electric locomotive is not the power available, as is the case with the steam locomotive, but in the capacity of the motors, and is usually fixed by the heating of their coils. An electric locomotive may safely develop for a short time an output which far exceeds its normal continuous capacity. The power and speed characteristics of electric locomotives therefore differ from those of steam locomotives.

34 The three types of electric motors have certain fundamental differences in speed performance which are important factors in determining the advantages, disadvantages and limitations of the several systems.

THE DIRECT-CURRENT MOTOR

35 The characteristics of the direct-current series railway motor are well known. It automatically adjusts its speed in accordance with the load, running more slowly if the weight of the train be greater, or the grade steeper. The speed with a given load, however, is definite; it is dependent upon the voltage applied to the motor and cannot readily be varied. It is true that the speed can be decreased by

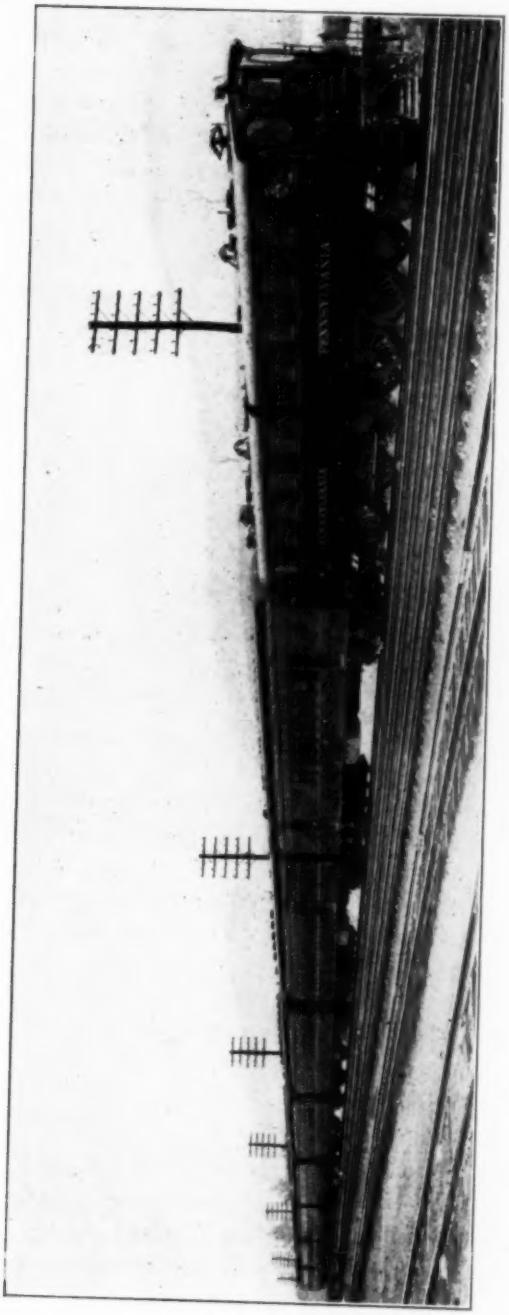


FIG. 3 PENNSYLVANIA ELECTRIC LOCOMOTIVE WITH ALL STEEL CAR TRAIN FOR OPERATION INTO THE NEW YORK STATION

inserting a resistance in the motor circuit, but this is wasteful and is inadmissible except as a temporary expedient. It is true also that the motors may be connected in series, thus dividing the pressure between two motors, and thereby reducing the speed one-half; or if among four motors, to one-quarter speed. As the system of current supply involves a fixed voltage, it is obvious that for emergencies no speeds much above the maximum speed determined in the construction of the motor can be obtained. Furthermore, on account of the high cost involved in maintaining a practically constant voltage throughout the system, the voltage supplied to the motors often decreases considerably at the end of long lines, at the time of heavy load, thereby further reducing the speed attainable. It often happens in railway service that a locomotive should be operated somewhat above the normal speed, and sometimes a locomotive designed for freight service has to be pressed into passenger service. In such cases the speed with the direct-current locomotive would be considerably less than that necessary to maintain the schedule speed. A special form of field control can be used, in certain cases, for varying the speed, although this has so far been utilized to a very limited extent.

THE THREE-PHASE MOTOR

36 On the three-phase system, the motor is inherently a constant-speed motor; it runs at approximately the same speed at light load and at full load; it runs at nearly the same speed up a grade as on level track, although the horsepower required on the grade may be several times that on the level. Conversely, it can run no faster on a level than it can climb a grade. In order to give a lower speed however, the motors may be arranged upon the locomotive in pairs in a manner equivalent to the arrangement of two continuous-current motors in series, just described. Motors may also be arranged for two or more speeds, but this involves some complication in windings and connections. In all cases lower speeds can be secured by the introduction of resistances which increase the losses and lower the efficiency. In no case can the speed in any of the arrangements of motors be appreciably higher at very light load than it is at full load.

37 The motors are of the induction type without commutators and their inherent limitations, and are of relative simplicity in construction. The current is usually supplied at 3000 volts from two overhead lines through two sets of current collectors.

38 With three-phase motors as now constructed and arranged upon locomotives, it is possible with no additional complication so to utilize the motors when locomotives are moving trains upon a descending grade, that they become generators and return current to the line, a feature of value in certain mountainous districts but not of controlling importance in the selection of a universal system.

THE SINGLE-PHASE MOTOR

39 The single-phase railway motor is a series motor with speed characteristics very similar to those of the direct-current motor,

FIG. 4 TYPICAL SECTION SHOWING THIRD RAIL, TRANSMISSION LINE AND SIGNAL BRIDGE OF THE NEW YORK CENTRAL AND HUDSON RIVER RAILROAD

as the speed at a given voltage is greater or less, depending upon the load. The speed with a given load is also greater or less, depending upon the pressure applied to the motor; and this is not limited, as with direct-current motors, to that supplied by the circuit, and to one-half and one-fourth of that pressure, but is capable of adjustment to any desired degree of refinement by means of auxiliary connections from the secondary winding of the transformer on the locomotive, which is necessary for reducing the line voltage of 11,000 volts to the lower voltage required by the motors. Not only may numerous voltages less than the normal be arranged for lower speeds, but higher voltages can be provided to make possible speeds considerably above

the normal. In this simple manner a wide range of efficient speed adjustment is secured which is impossible with other systems.

40 Like the throttle lever of the steam locomotive, the control lever of the single-phase locomotive may be placed in any one of its numerous notches to maintain the required speed. This facility of efficient operation over a wide range of speed and power requirements is one of the especially valuable features of the single-phase system. This difference, however, may be noted: the ability of the steam locomotive to maintain its speed continuously with heavy loads depends upon the capacity of the boiler; on the other hand, the electric locomotive has an ample supply of energy available, drawn from a large power house, and the limit of its endurance is determined by the safe temperature of the motor.

41 The question of determination of the frequency for use on single-phase railways is one of very great importance. Twenty-five cycles is in general use for power transmission purposes and has been adopted by nearly all the single-phase railroads now operating. The Midi Railway of France has adopted 15 cycles. The lower frequency permits of a marked reduction in the size of a motor for a given output, or conversely of a considerable increase in output from a motor of given dimensions and weight. Three-phase installations in nearly all cases employ approximately 15 cycles. The choice of frequency is one of the most involved, difficult and important problems now presented for solution.

SUMMARY

42 Locomotives equipped with each of the three types of motors have been in successful operation and have demonstrated their usefulness, capacity and reliability in practical railway service. The three-phase motor, having a definite constant-speed characteristic, is particularly adapted to certain conditions; but on the other hand it has a less general adaptability to the ordinary varying conditions of railway operation. The single-phase motor has a facility of voltage control which gives an efficient means of speed adjustment, and is in this particular superior to other systems. The relative weights and costs of the several types of motors, and of the locomotives designed to accommodate them, depend upon so many conditions that comparisons must necessarily be general. It will be found, however, that these differences in locomotive cost are in many cases more than offset by the cost of the other elements in the electrical system.

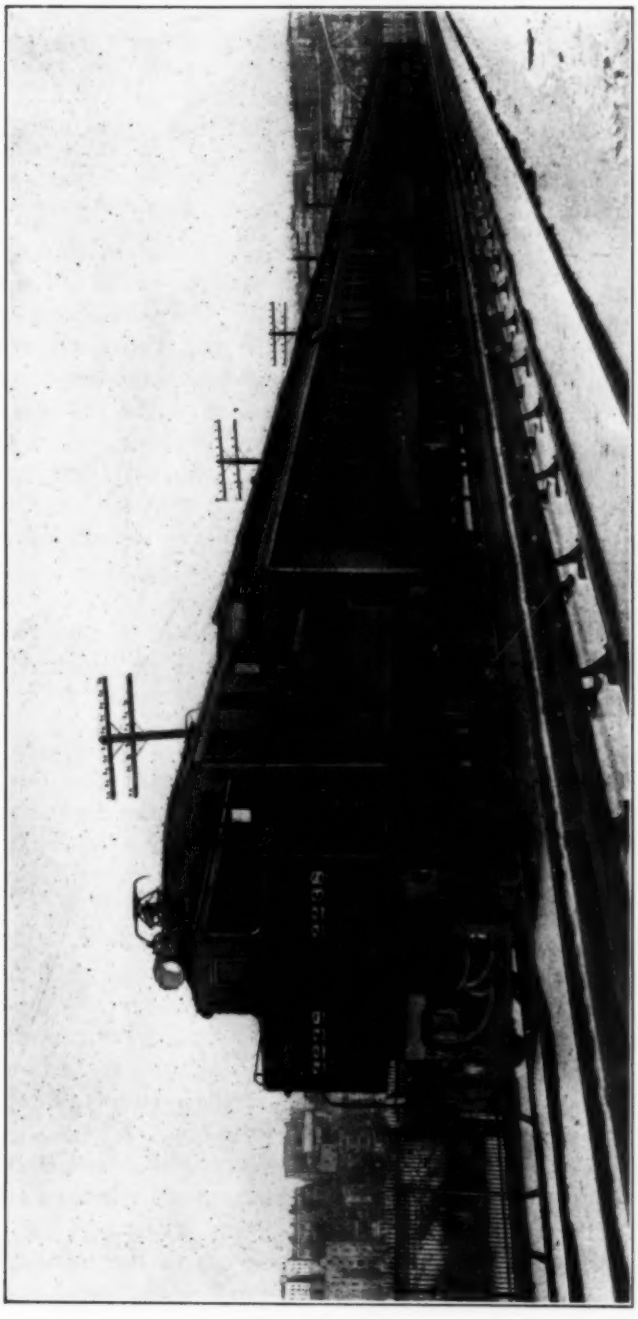


FIG. 5 NEW YORK CENTRAL AND HUDSON RIVER RAILROAD LOCOMOTIVE DRAWING 20TH CENTURY LIMITED TRAIN

43 The control apparatus for all types of locomotives has been developed so that it is reliable and convenient in operation. For each system a small master controller serves to operate by auxiliary means the necessary electric switches for the control of the motors of one locomotive, or to operate simultaneously as a single unit the motors on two or more locomotives or cars in a train.

Transmission of Power from Power House to Locomotive

44 The controlling factor in the cost of electrification in nearly all cases is the system for transmitting power from the power house to the locomotive, and not the locomotive itself. The choice between the several systems must, therefore, be based upon a comparison of the complete systems. The differences between the methods of transmitting power are of far greater importance than the differences between power houses or between locomotives. The current for all systems is generated in usual practice as high-tension alternating current, for the reason that electric energy can be most economically transmitted by high-tension alternating current even though it is in some cases converted into direct current.

45 The transmission systems in use for the three types of locomotives are illustrated in Appendix No. 3. Even a superficial glance at these diagrams brings several points into prominence, as follows:

THE DIRECT-CURRENT SYSTEM

46 For the direct-current locomotive the apparatus which intervenes between the alternating current-generator and the locomotive consists of a number of links or elements through which the electric energy must pass, one after the other. These consist of:

a Raising transformers in groups of three.

b A transmission line of three wires, sub-stations, which require attendance, containing

c Transformers in groups of three, and

d Rotary converters for receiving the alternating current and delivering direct current.

e A third-rail contact conductor, which for heavy work must often be supplemented by copper feeders.

f The track return circuit, which must be provided with heavy bonds, and in certain cases supplemented by feeders and so-called negative boosters.

47 It is necessary to maintain the alignment of the third rail within close limits both in its distance from the track rails and in its

FIG. 6 MULTIPLE UNIT TRAIN IN SUBURBAN SERVICE ON NEW YORK CENTRAL AND HUDSON RIVER RAILROAD

elevation above them, as the contact shoe can have only a small range of automatic adjustment.

THE THREE-PHASE SYSTEM

48 For the three-phase locomotives the respective links between the generator and the locomotives are:

a Raising transformers in groups of three.
b Transmission line of three wires.
c Sub-station transformers in groups of three.
d Two overhead wires as the contact system.
e A track return which usually requires nothing but inexpensive bonding.

49 The two overhead trolley wires require a double system of overhead construction, as the wires must be kept separate and well insulated from one another; the two must be maintained at equal height above the track and at switches and cross-overs the construction is complicated.

THE SINGLE-PHASE SYSTEM

50 For single-phase locomotives there is:

a A raising transformer.
b A transmission line of two wires and sub-stations widely spaced, each containing
c A lowering transformer, which supplies
d A single trolley wire.
e A track return, usually requiring nothing but inexpensive bonding.

51 In certain cases where the distance from the power station is not more than 15 or 20 miles, the single-phase trolley can be supplied directly from the power house, so that only one single element, i.e., the trolley wire, intervenes between the generators and the locomotives.

52 The single trolley wire permits a relatively wide range in height, as the pantagraph trolley automatically adjusts itself to the position of the trolley wire. In some cases the wire has a normal height of 22 ft., but is carried under bridges where the limit is 15½ ft.

53 The three types of railway motors, and the three respective systems for conveying power from the generating station to the locomotives, have all successfully demonstrated their ability to operate railway trains. It is not my purpose to urge the adoption of a particular system, but rather to point out some of the well-known char-

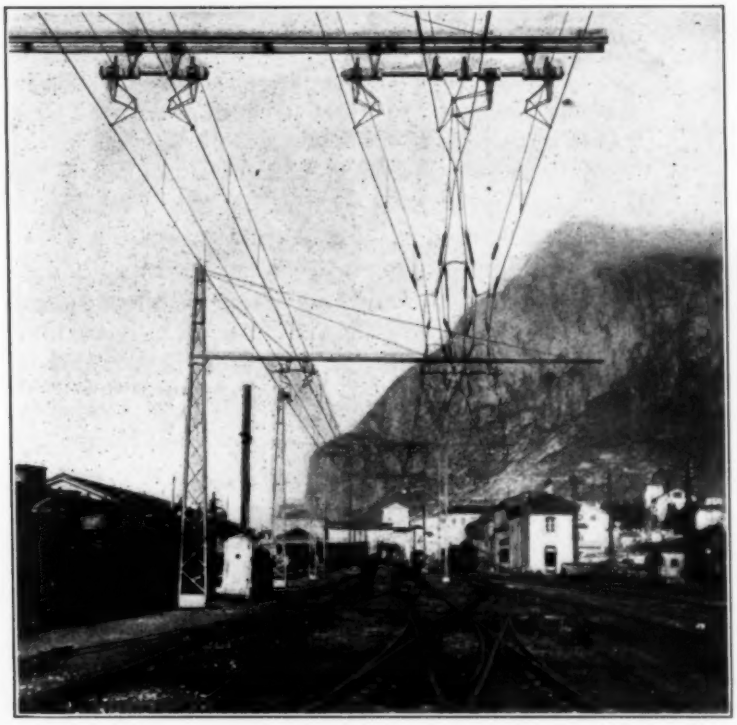


FIG. 7 OVERHEAD CONSTRUCTION ON ITALIAN RAILWAYS, LECCO-CALOLZIO LINE

acteristics of these systems which have a bearing upon their limitations and their general adaptability to railway conditions, and to urge the great gain which will result from a single universal system.

54 As the electrical manufacturing companies with which my name is associated manufacture and install all kinds of direct and alternating-current apparatus, I may be pardoned for saying that I have not permitted my judgment to be influenced by any personal material interests, and that I have treated this subject so as to give others the benefit of a long experience, acquired under circumstances most favorable to ascertaining the facts.

REQUISITES FOR A UNIVERSAL ELECTRIC SYSTEM

55 In selecting a proper electrical system for railway operation, it will probably be generally conceded that the following elements are of prime importance:

a The electric locomotives should be capable of performing the same kinds of service which the steam locomotives

now perform. This will be most readily secured by electric locomotives which can practically duplicate the steam locomotives in speed and power characteristics. This includes a wide range of performance, embracing through passenger service at different schedule speeds; local passenger service; through freight service in heavy trains; the handling of local freight by short trains; and a variety of switching, terminal and transfer movements. This naturally calls for wide variation in tractive effort and in speed, both for the operation of different kinds of trains, and also for the operation of the same train under the varying conditions usually incident to railway service.

The electric locomotive should be capable of exceeding the steam locomotive in its power capacity. It should be able to handle heavier trains and loads, to operate at higher speeds, and in general to exceed the ordinary limits of the steam locomotive in these regards. The readiness with which several electric locomotives can be operated as a single unit enables any amount of power to be applied to a train.

c The electric system should adapt itself to requirements beyond the ordinary limitations of the steam locomotive in small as well as large things. It should be adapted for use on branch lines, and for light passenger and freight service similar to that so profitably conducted by interurban electric roads, which in many cases run parallel to steam roads, not only taking away the traffic of the steam roads, but building up a new and highly profitable traffic, both in passenger and in express service.

d A universal electrical system requires that power should be transmitted economically over long distances and supplied to the contact conductor. The system should utilize the most highly perfected apparatus for the electric transmission of energy and its transformation into suitable pressures for use.

e The contact conductor in an ideal system should be economical to construct, both for the heaviest locomotives where the traffic is dense, and for light service on branch lines. It should impose minimum inconvenience to track maintenance; should give minimum probability of disarrange-

ment in case of derailment, or in case of snow and sleet, and should in general be so placed and constructed as to give a maximum assurance of continuity of service.

56 The use now made of electricity in steam railway service has been brought about, generally speaking, through compulsion. The steam locomotive has reached its limitations and has been found unsuitable and inadequate in tunnels or in terminal service. Even where other considerations may have been controlling, the problem has usually been a specific one of electrifying a relatively small area. The problem has been solved by considering those factors which were of immediate importance, without giving weight to uniformity with other systems or of extension.

57 Now the natural course of development will be the extension of these limited zones, until after a time they meet. Then there will arise great inconvenience and expense if the systems are unlike. For the present it may be a matter of little moment whether different systems have their contact conductors in the same position, or whether the character of the current used is the same or different. As previously stated, in the early days of railroading, it was of little consequence whether the tracks of the different systems in various parts of the country were alike or unlike, but later it did make a vital difference, and the variation resulted in financial burdens which even yet lie heavily on some railways. It is this large view into the future of electrical service which should be taken by those responsible for electric railway development.

THE FUTURE OF ELECTRIFICATION OF RAILWAYS

58 The complete electrification of a railway will necessitate a rearrangement of ideas and practices in regard to operations. Coaling and watering places will not be needed; passenger trains will be differently composed, some classes being of less weight; and they will operate more frequently, thus promoting travel; other trains will be heavier than at present, or will operate at higher speeds; and branch lines, by the use of electrically fitted cars, can be given a through service not now enjoyed.

59 The movement of freight will undergo great changes, due to the fact that electric locomotives can be constructed with great excess capacity, enabling them to move longer trains at schedule speed on rising gradients.

60 The large percentage of shunting operations due entirely to the use of steam locomotives will no longer be required.

61 The railway companies can combine upon some coöperative plan for the generation of electricity, thereby effecting large savings in capital expenditures; and can utilize their own rights of way for the transmission of the current, not only for the operation of trains but for many other useful purposes.

62 Notwithstanding the fact that great strides have already been made in cheapening the cost of generating electricity by steam engines, I foresee, from the progress made in the development of gas and oil engine power, a still further reduction in cost which will accelerate the work of electrifying existing railways.

63 One important aspect of this great question will engage the thoughtful consideration of every government, namely, the military necessity for uniform railway equipment in time of war.

64 There will be serious difficulties to surmount in the selection of a general system. There naturally will be arguments in favor of one or another of the systems now in use and the inclination of those who have adopted a particular system to advocate its general use. There will be enthusiastic inventors, and there will be many advocates of the common view, namely, that there is room for several systems and that each system will best meet the requirements of a particular case. There will be those who give undue weight to some feature of minor importance, such as a particular type of motor or of locomotive, instead of giving a broad consideration to the whole system, and recognizing that, in the general problem of railway electrification, facility and economy in transmitting power from the power house to the locomotive, are of controlling importance.

65 Were there now only one system to be considered, there would be a concentration of the energy of thousands on the perfecting and simplifying of the apparatus for that system, to the advantage of railway companies and of manufacturers.

66 In conclusion, I can only repeat, and earnestly recommend to the serious consideration of railway engineers and those in authority, the pressing need of determining the system which admits of the largest extension of railway electrification and of a prompt selection of those standards of electrification which will render possible a complete interchange of traffic in order to save expense in the future and to avoid difficulties and delays certain to arise unless some common understanding is arrived at very shortly.

APPENDIX NO. 1

THE SINGLE-PHASE SYSTEM ON THE NEW YORK, NEW HAVEN & HARTFORD RAILROAD

The most important installation of single-phase apparatus is that of the New York, New Haven & Hartford Railroad, leading out of New York City. Practically all the railroad service between New York and Boston, as well as the New England states, is over the four tracks of this railroad. The trains pass into the Grand Central Station in New York City over the lines of the New York Central & Hudson River Railroad, which is electrically equipped with the third-rail system for operation by direct current at 650 volts. Selection of the system for the New Haven railroad was restricted by the necessity of operating the New Haven trains over the New York Central tracks; but the decision was in favor of the single-phase system, notwithstanding the limitation that the locomotives must operate successively both by single-phase current and direct current.

102 The trains of the New Haven system leaving the Grand Central Station pass over 12 miles of the tracks of the New York Central system, operating from the third rail by direct current. They then pass to the New Haven tracks at full speed, receiving alternating current at 11,000 volts from the overhead trolley wires which extend 21 miles to Stamford, a total distance of 33 miles from New York, this being the end of the initial installation of the single-phase system.

103 The power house is located near the Stamford end of the electrified section and contains four 11,000-volt turbo-generators having an aggregate capacity of over 16,000 kw. The current passes directly from the generators to the trolley wires, as illustrated in Fig. 18 and in the last diagram of Fig. 19.

104 The overhead trolley system consists of a steel contact trolley wire suspended every 10 ft. from a copper trolley wire, which in turn is suspended at intermediate points from two steel catenary cables by triangular-shaped hangers. These cables are supported upon insulators resting upon steel bridges spaced at distances of 300 ft. along the right of way. The construction is shown in Fig. 1 of the paper.

105 As in general there are four tracks and in some cases more, the comparatively light steel bridges are made to span the right of way and to carry as many sets of the trolley conductors as there are tracks. Stronger bridges to which the catenary cables are anchored are located about every two miles. At certain points these anchor bridges are utilized for supporting the block signals and also to carry oil circuit breakers which permit the trolley wires to be sectionalized for service operation or in emergencies. Normally all the trolley wires and the supporting cables over all the tracks are connected together electrically and also to the source of supply at the power house.

106 There are 41 locomotives in regu'ar operation, and also four motor cars with six trail cars operating on the multiple unit system in suburban service. The alternating current is taken from the overhead trolley wire by a pantagraph which presses a shoe against the wire. The direct current on the New York Central zone is obtained from the third rail by means of ordinary sliding contact shoes. Both the pantagraph and the contact shoes are manipulated by compressed air. The locomotive is described in Par. 203.

107 For reasons of economy in operation the locomotives were built under the requirement that each should be capable of hauling a 200-ton train from New York to New Haven, making all station stops in accordance with the regular schedules, or an express train of 250 tons, and that the locomotives should be so arranged that two or more could be operated by a single engineer for the movement of heavier trains. The particular size selected permits about 75 per cent of the trains to be operated by a single unit.

TABLE 1 RECORD OF SINGLE-PHASE SERVICE
NEW YORK, NEW HAVEN & HARTFORD RAILROAD FOR 12 MONTHS

	Total Miles Run	No. Locomotive Delays	Miles Run per Locomotive Delay	No. of Power House Delays	No. of Line Delays
1909					
April	146,189	9	16,243	..	3
May	155,551	25	6,222	1	3
June	166,759	14	11,911	..	4
July	183,434	13	14,110	..	2
August	177,714	14	12,694	..	5
September	189,656	14	13,547	..	1
October	174,400	11	15,854	1	4
November	173,370	10	17,337	..	1
December	167,808	23	7,296	..	3
1910					
January	163,274	28	5,831	..	2
February	138,929	12	11,577	..	1
March	156,901	12	13,075	..	1

108 During the past year, the electric service has surpassed in efficiency all records previously obtained on this division with steam locomotives. The actual figures are given in Table 1, which covers the movement of passenger trains over the 12 miles of third-rail operation and 21 miles of single-phase operation, for which 41 locomotives, that have been used from 22 to 33 months, were available.

109 The early fears as to difficulties in commutation have been dispelled by the records of performance, as many of the motors have operated over 100,000 miles without turning or even sandpapering the commutators, and the brushes show an average life of 40,000 to 45,000 miles.

110 The average number of miles run per locomotive delay during the year exceeds 12,000, equivalent to a dozen trips between New York and Chicago, or thirty trips between London and Glasgow.

111 The locomotive delays (many of which only slightly exceeded one minute duration) include not only those from electrical causes, but from mechanical

defects as well, such as loose tires, burst airhose, hot journal boxes, frozen steam hose, etc. A comparatively large number of delays in December and January were due to the very severe weather and the unusual amount of snow and ice. These locomotives have been making regularly an average of about four and one-half trips of 33 miles per day, hauling trains 25 to 50 per cent heavier, or even more in the case of express trains, than the locomotives were guaranteed to handle. Most of the locomotives have run about 100,000 miles, but there is seldom more than one (which is 2½ per cent of the whole number), out of service for repairs, a record said by the officials of the company to be much better than for the steam locomotives which were replaced. These officials also say that the cost of maintenance per mile and the number of miles run per electric locomotive are far more favorable than with steam locomotives, even with the present very short run of 33 miles.

112 The cost of maintenance of the distribution system is relatively small compared with that of the low-voltage third-rail system. The delays due to the transmission lines and overhead construction, though few in number, include those brought about by extraordinary conditions, such as steam from switch engines and by wrong operation of switches.

113 The heaviest traffic on the New York division of the New Haven road, and the occasion on which delays would be most deplored, is on the day of the annual intercollegiate football game at New Haven. The service on this day for 1908 and 1909 was as follows:

	1908	1909
Regular trains	128	126
Special trains	30	29
Total trains	158	155
Number of train delays	2	0
Total duration of delays	17 min.	

114 In considering the capability of the single-phase system for continuous performance, the record of the six single-phase locomotives in service at the St. Clair Tunnel of the Grand Trunk Railway is worthy of mention. These locomotives have now been running two years and have made about 70,000 miles each, averaging about 100 miles per day, or 25 trips of 4 miles. It has not been necessary to use a steam locomotive since the regular electric service was started (May 1908) and during the last 12 months the service has been responsible for but one train delay, of eight minutes. The locomotive is described in Par. 204.

APPENDIX NO. 2

DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN

The locomotives on which data are given were built for heavy railway service. They are for passenger service and for combined passenger and freight, and include locomotives for direct current, three-phase current, and single-phase alternating current, and others adapted for operation on either single-phase alternating current or direct current.

202 A brief description of these locomotives follows, including mention of some of their notable features.

LOCOMOTIVES OF THE WESTINGHOUSE ELECTRIC & MFG. CO.

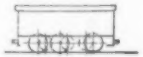
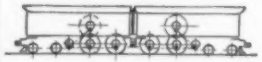
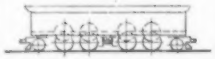
203 Referring to Table 2, the first column covers locomotives built for the New York, New Haven & Hartford Railroad, for operation on their electrified zone between New York and New Haven. The electrical system demanded that the locomotives be capable of operation both on single-phase and direct current. There are 41 of these locomotives in operation. A gearless concentric motor for each driving axle is mounted on a quill flexibly connected to the driving wheels. The dead weight on the axles is thus reduced to a minimum. Two of these locomotives are shown attached to the train in Fig. 1 of the paper.

204 The second column covers locomotives built for the Grand Trunk Railway for operation in the St. Clair Tunnel under the St. Clair River. These locomotives are designed for operation with single-phase current only. They are handling the entire freight and passenger traffic through the tunnel. A report of the operation of these locomotives is given in the last paragraph of Appendix No. 1. The locomotive is shown in Fig. 8.

205 The third column covers locomotives built for the Pennsylvania Railroad for operation in their New York tunnel. They are for passenger service only and operate on direct current at 600 volts on the conductor. The first locomotive has been run 17,000 miles on test. The center of gravity of these locomotives is high, as the motor is mounted well above the driving axles. The transmission from motor to wheels is by cranks and connecting rods. These parts are protected from possible damage due to short circuit by interposing between the armature and its shaft a friction clutch which will slip before damaging stresses are imposed on the transmission. The motors are the largest railway motors ever built and are provided with commutating poles, making possible the use of a shunted field control which is applied to these locomotives. The locomotive is shown in Figs. 9 and 10.

206 The fourth column covers a locomotive built for the New York, New Haven & Hartford Railroad for use in high speed freight and medium-speed passenger service. It also is fitted for operation both with single-phase and direct current.

TABLE 2 DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN
BUILT BY THE WESTINGHOUSE ELECTRIC & MFG. CO.

					
Built for	New Haven	Grand Trunk St. Clair Tunnel	Pennsylvania	New Haven	New Haven
Electric system	A.C., D.C.	A.C.	D.C.	A.C., D.C.	A.C., D.C.
Service	Passenger	Frt. & Pass.	Passenger	Frt. & Pass.	Frt. & Pass.
First placed in service	July 1907	February 1908	17,000-mile test	3000-mile test	building
No. in service or on order May 1910	41	6	24	1	1
No. motors per locomotive	4	3	2	4	2
Armature diameter, inches	39½	30	56	39½	76
Core length, including vent opening, inches	18	14¾	23	13	13
Weight one motor, pounds	16,420	15,660	45,000	19,770	41,600
Weight all motors on locomotive	65,680	46,980	90,000	79,080	83,200
Weight all electrical parts	110,400	58,400	127,200	130,000	135,000
Weight all mechanical parts	94,100	73,600	204,800	130,000	125,000
Weight complete locomotive	204,500	132,000	332,000	260,000	260,000
Weight on driving wheels	162,000	132,000	207,800	180,000	180,000
Weight complete locomotive for A.C. operation	196,000	132,000	D.C.	241,000	240,000
Max. guar't'd speed, miles per hr.	about 86	30	about 80	45	45
Feature limiting speed	track	armatures	connecting rod	armatures	armatures
Max. tractive effort	19,200	43,800	69,300	40,000	40,000
Loco. wt. in excess of 18% adhesion Max. T.E., A.C. operation	88,700	none	none	18,500	17,500
Designed for trailing load, tons	250	500	550	{1500 freight / 800 pass.}	{1500 freight / 800 pass.}
Balance speed on level with above load	about 75	about 25	60	{35 freight / 45 pass.}	{35 freight / 45 pass.}

It has been run approximately 3000 miles in test service, actually hauling regular freight trains, including the steam locomotives, over the electrified section of the railroad on the normal schedules for the movement of these trains. A pinion at each end of the motor meshes with a flexible gear whose center is rigidly secured to the quill surrounding the axle, the flexible gear overcoming the difficulties in securing tooth alignment and division of load which are liable to occur when rigid twin gears are used. It is the only electric locomotive equipped with spur-geared motors which are bolted rigidly to the spring-supported parts of the locomotive. Each driving wheel is driven through helical springs, the arrangement being such that the driving wheel has practically free vertical play. The locomotive has two trucks, the draw-bar pull being transmitted

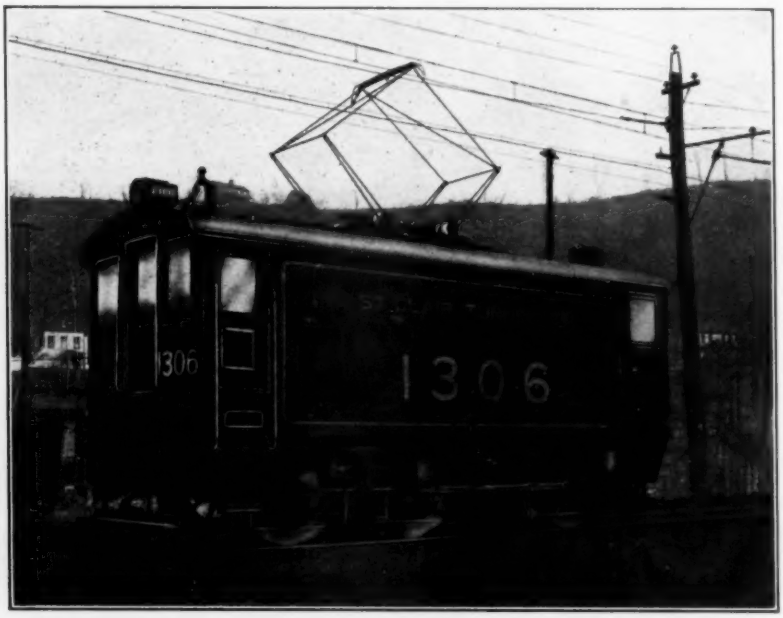


FIG. 8 SINGLE-PHASE LOCOMOTIVE FOR PASSENGER AND FREIGHT SERVICE IN ST. CLAIR TUNNEL OF GRAND TRUNK RAILWAY

through the truck frames. The body is spring-mounted on friction plates in place of being carried on truck center pins in the usual manner. It is an exceptionally easy riding machine with very low rolling friction. The performance has been satisfactory, and a speed of 40 miles per hour was attained on level track with a 1600-ton train. See Figs. 11 and 12.

207 The fifth column covers a locomotive for the same railroad and service as that just described. The comparison between geared and connecting-rod motors for identical service is a very interesting feature of this development. The weights given in both the fourth and fifth columns are those on which locomotives of these types would generally be built. The actual locomotives are somewhat

heavier, due to particular features of design not inherent in the type. The effect on the connecting rods and pins of the pulsating torque of a single-phase current is avoided by the introduction of a flexible connection between the armature and its shaft. This locomotive has not been tested.

208 These last two locomotives were ordered by the New Haven road to demonstrate the practicability of electric traction for freight service and to assist in determining the most suitable kind or type of locomotive.

LOCOMOTIVES OF THE GENERAL ELECTRIC COMPANY

209 The first column of Table 3 covers locomotives built for the New York Central & Hudson River Railroad for operation on the electrified zone of the New York City terminal. Forty-seven of these locomotives are in use, the first having been put in operation in July 1906. They are used for passenger service only, and operate on direct current at 600 volts. The mechanical equipment of this locomotive consists of a main driving wheel base with four driving axles and a four-wheel guiding truck at either end. The motor is of the bi-polar gearless type, the armature being mounted directly on the driving axle, and the mechanical structure of the locomotive forming a portion of the magnetic circuit of the motors. The characteristic feature of the locomotive is the simplicity of its electrical and mechanical construction, which contributes to its high efficiency and low maintenance cost. The locomotive is shown in Figs. 5 and 13.

210 The second column of Table 3 covers locomotives built for operation at the Detroit River Tunnel. These are to be used for both freight and passenger service between Detroit, Mich., and Windsor, Ont., and will be operated at 600 volts, direct current. The running gear consists of two trucks connected together with a massive hinge so as to form a single articulated wheel base, and buffers carried on the outer end frames of the trucks. The motor is of the direct-current geared type with commutating poles and is interesting as the first application of the commutating pole motor to this class of service. Twin gearing is used between the motor and driving axle, and consists of a pinion at each end of the armature shaft and a corresponding gear on the axle. The use of twin gearing relieves the armature shaft of torsional strains and maintains the parallelism of the shaft and axle. Five of these locomotives have been built and are awaiting completion of the tunnel. While they are not in actual operation, extensive tests made on a test track in hauling and accelerating freight trains up to 1500 tons in weight have proved that this type is very satisfactory for the service.

211 The third column covers locomotives built for the Baltimore & Ohio Railroad for operation of both freight and passenger service through the Baltimore Belt Line Tunnel. Two of these locomotives are in use and operate on direct current at 600 volts. The general design is similar to the Detroit Tunnel locomotive described above and the same type of motors are used, but the motors are geared for higher speed in order to meet the speeds required by passenger service on the relatively lighter grades of the Baltimore Tunnel.

212 The fourth column covers locomotives built for the operation of freight and passenger trains through the Cascade Tunnel of the Great Northern Railway. These locomotives are designed for three-phase operation at 25 cycles and 6600 volts on the trolley. The mechanical structure consists of an articulated wheel base similar to that of the Detroit River Tunnel locomotive described above. The a motor is three-phase induction motor with external secondary resistance and

FIG. 9 PENNSYLVANIA DOUBLE ARTICULATED LOCOMOTIVE FOR THE NEW YORK TUNNEL SERVICE

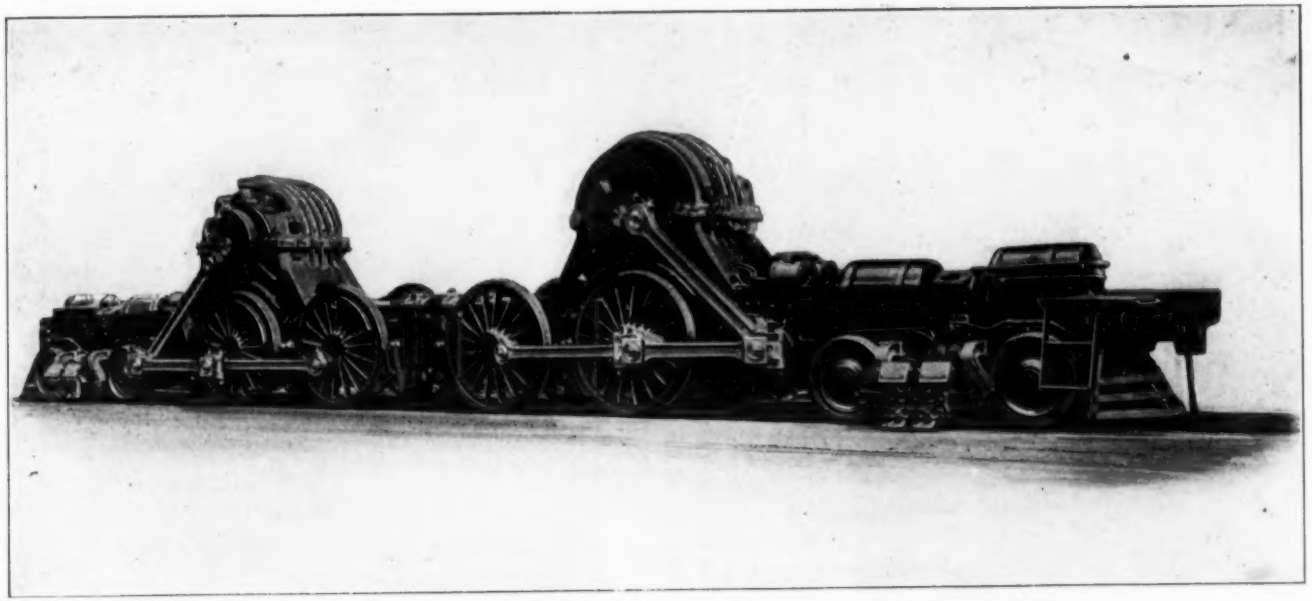


FIG. 10 UNDER FRAMES, MOTORS AND DRIVING MECHANISM OF PENNSYLVANIA DOUBLE ARTICULATED LOCOMOTIVE FOR NEW YORK TUNNEL SERVICE

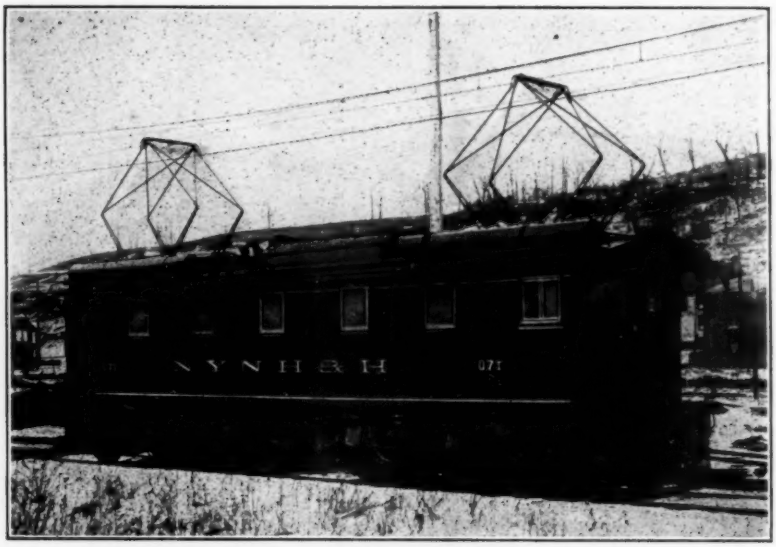


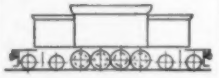
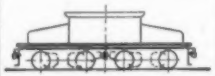
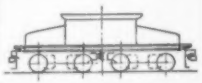
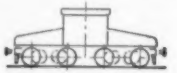
FIG. 11 SINGLE-PHASE AND DIRECT-CURRENT LOCOMOTIVE FOR PASSENGER AND FREIGHT SERVICE ON THE NEW YORK, NEW HAVEN & HARTFORD RAILROAD
MOTORS WITH FLEXIBLE TWIN SPUR GEARS ARE PLACED DIRECTLY OVER DRIVING AXLES

fitted with a gear at each end of the armature shaft. The service for which they are ultimately designed is the operation of a division 57 miles long with ruling

FIG. 12 VIEW SHOWING ARRANGEMENT OF MOTORS OVER DRIVING AXLES FOR LOCOMOTIVE ILLUSTRATED IN FIG. 11

TABLE 3 DATA ON ELECTRIC LOCOMOTIVES OF AMERICAN DESIGN

BUILT BY THE GENERAL ELECTRIC COMPANY

					
Built for	N. Y. C. & H. R. R.	Detroit River Tunnel	B. & O. R. R.	Great Northern	Paris-Orleans
Electric system	D.C.	D.C.	D.C.	3-phase	D.C.
Service	Passenger	Frt. & Pass.	Frt. & Pass.	Frt. & Pass.	Passenger
First placed in service	July 1906	tests completed	March 1910	July 1909	1899
No. in service or on order May 1910	47	6	2	4	11
No. motors per locomotive	4	4	4	4	4
Armature diameter, inches	29	25	25	35¾	23½
Core length, including vent. opening, inches	19	11½	11½	16¼	12
Weight one motor, pounds	18,150	10,560	10,560	15,000	8,855
Weight all motors on locomotive	72,600	42,240	42,240	60,000	35,420
Weight all electrical parts	91,200	54,000	54,000	109,000	42,500
Weight all mechanical parts	138,800	146,000	130,000	121,000	67,500
Weight complete locomotive	230,000	200,000	184,000	230,000	110,000
Weight on driving wheels	141,000	200,000	184,000	230,000	110,000
Weight complete locomotive for A.C. operation	D.C.	D.C.	D.C.	230,000	D.C.
Max. guar't'd speed, miles per hr.	75	30	55	30	45
Feature limiting speed	track	armature	armature	armature	armature
Max. tractive effort	47,000	67,000	61,000	77,000	37,000
Loco. wt. in excess of 18% adhesion Max. T.E., A.C. operation	none	none	none	none	none
Designed for trailing load, tons					
Freight		900 on 600 2% grade	850 on 500 1½% grade	500 on 2.2% grade	
Passenger					
Balance speed on level with above load	435 / 63	Freight 20.5 / Pass. 22	Freight 26 / Pass. 30	15	300 / 32

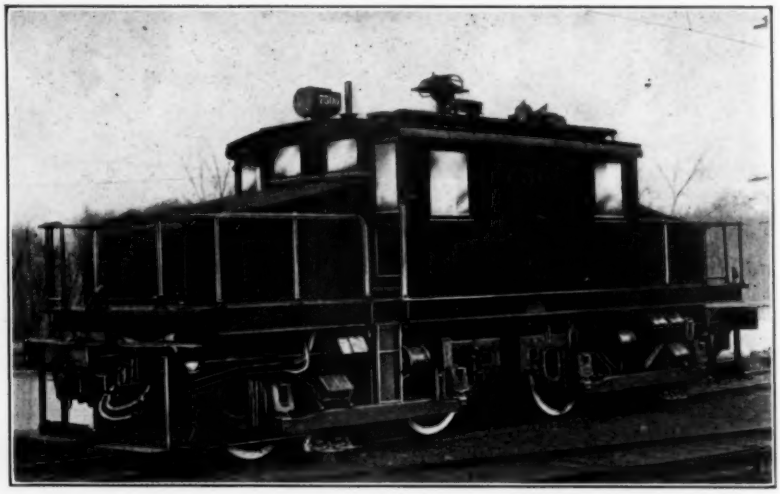


FIG. 13 ELECTRIC LOCOMOTIVE ON THE NEW YORK CENTRAL & HUDSON RIVER RAILROAD

grades of 2 . per cent and an average grade of 1.55 per cent. Four of these locomotives are in service and it may be of interest to note that they were involved in the disastrous avalanche of March 1, 1910, which swept through the electrified yards at Wellington, Wash. The locomotive is shown in Fig. 14.

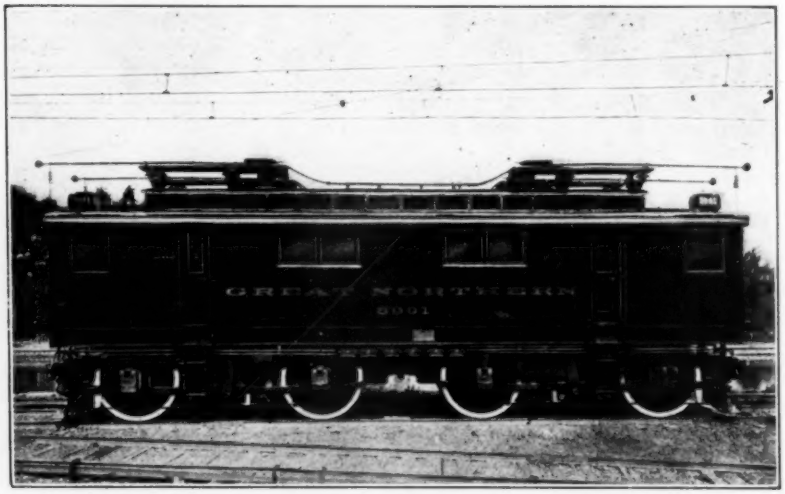


FIG. 14 ELECTRIC LOCOMOTIVE ON THE GREAT NORTHERN RAILWAY

213 The fifth column covers locomotives built for the Paris-Orleans Railway, for use in hauling passenger trains from the Austerlitz Station to the Quai d'Orsay. They are designed for operating on 600 volts, direct current. These locomotives are historically of interest, the first one of them having been delivered in 1899, and twelve being now in service. Each locomotive has two independent trucks, each truck equipped with two geared motors, and carrying weight of cab and platform on the center pin with draft gear and buffer attached to this platform. This represents a type of locomotive of which a large number have been built, and which has proved highly satisfactory for light and medium classes of service.

APPENDIX NO. 3

COMPARISON OF SYSTEMS OF ELECTRIFICATION

The salient features of the three systems of railway electrification are presented in a number of diagrams so arranged as to permit of a ready comparison between their essential characteristics, particularly in the circuits and apparatus which transmit the power from the power station to the locomotive.

302 The perspective sketches, Figs. 15 to 18, show the commonly used types of apparatus and circuits in a simple and elementary way, as only a single generator and a single sub-station, containing but one group of units, are shown, and auxiliaries such as switchboard apparatus are altogether omitted.

303 Fig. 15, showing the direct-current system, illustrates the alternating-current generator, the three raising transformers, the three-phase transmission circuit, the three sub-station lower transformers, and the rotary converter which supplies direct current to the third-rail contact system.

304 Fig. 16, illustrating the three-phase system, is similar to Fig. 15 up to the point where the power passes the sub-station transformers. Power is then delivered directly to the contact system, consisting of two overhead trolley wires, shown suspended from supporting cables in accordance with the commonly used catenary construction.

305 Fig. 17, presenting the single-phase system, has a similarity to the preceding sketch of the three-phase system, Fig. 16, and may be derived from it by simplifying its several elements. Single transformers instead of groups of three are found in the power house and sub-station. The transmission has two wires instead of three and there is but one trolley wire instead of two.

306 Fig. 18 shows the single-phase system where the distances are moderate and the generator can supply current directly to the trolley wire at 11,000 volts, thereby eliminating the high-tension transmission circuit and the sub-stations. This is the method employed in the single-phase installation on the New Haven system.

DIAGRAMS OF TRANSMISSION CIRCUITS AND SUB-STATIONS

307 Fig. 19 shows the arrangement of transmission lines and contact circuits and the relative number and location of sub-stations for each of the three systems.

308 The direct-current sketch, Fig. 19, shows the three-phase transmission line running from the power house to the sub-stations, which contain step-down transformers and rotary converters for changing the high-potential alternating current to low-potential direct current. It also shows the third rail supplemented by an auxiliary conductor or feeder. The track serves for the return circuit.

309 In a certain typical case it was found that the sub-stations should be approximately eight miles apart for a pressure of 600 volts in the direct-current system. If direct current were used at a pressure of 1200 volts, half of the sub-stations could be omitted.

310 The distances above mentioned are found to be proper for a particular case and the diagram is intended simply to show approximately the relative number of sub-stations required in the several systems. The actual distances in other cases may be more or less than those given. In the several systems employing a transmission line the distance may obviously be extended to include a greater number of sub-stations than are shown.

311 The three-phase sketch, Fig. 19, shows the three-phase transmission line and sub-stations containing transformers only, for reducing the high-potential alternating current to low-potential alternating current for use on the double overhead trolley system with track return. The sub-stations are spaced the same distance apart as those in the direct-current system. This arrangement of sub-stations is for 3300 volts on the trolley. With 6600 volts on the trolley, half of the sub-stations would be omitted.

312 The larger single-phase sketch, Fig. 19, shows a single-phase transmission line running to sub-stations containing transformers only, to reduce the high-potential alternating current of transmission to a suitable potential, 11,000 volts, for use on the single overhead trolley with track return.

313 The smaller single-phase sketch shows a single-phase line which is not too long to prevent the entire system from being fed directly from the generators without the intervention of transmission line or transformers between the generators and the trolley circuit. This sketch shows the method employed on the New Haven system.

314 In thickly populated districts congested with traffic, the generating stations, of which there should be not less than two in order to minimize interruptions to traffic, should probably be located at junction points or places demanding the greatest power and at distances not exceeding thirty or forty miles. With such a disposition of power houses, the overhead trolley wires will usually be sufficient for the supply of current. In like manner, where the traffic is not so heavy, the power houses can be placed at greater distances, bearing in mind, however, that the increase in traffic may subsequently demand intermediate power houses or sub-stations. In cases where power stations are long distances apart, the single trolley wire should probably be supplemented by an additional circuit in order to guard against interruptions due to defect in the trolley wire, and to give a sufficient supply of power for any contingency.

COMPARATIVE LOSSES, SHOWN IN FIG. 20

315 Fig. 20 shows the comparative losses between the generators and the locomotives for each of the three systems, based on a class of service where the input to the locomotives by the several systems is practically the same.

316 As some kinds of service render one type of motor with its auxiliary apparatus and control more efficient, while under other conditions it may be less efficient, this variable element has been eliminated by assuming the same power delivered to each locomotive as a basis for a general comparison of the transmission losses.

317 The total height of each column in the diagram indicates the total power delivered by the power house in the system designated. The height of the long portion at the lower part of each column indicates the amount of power which reaches the locomotive.

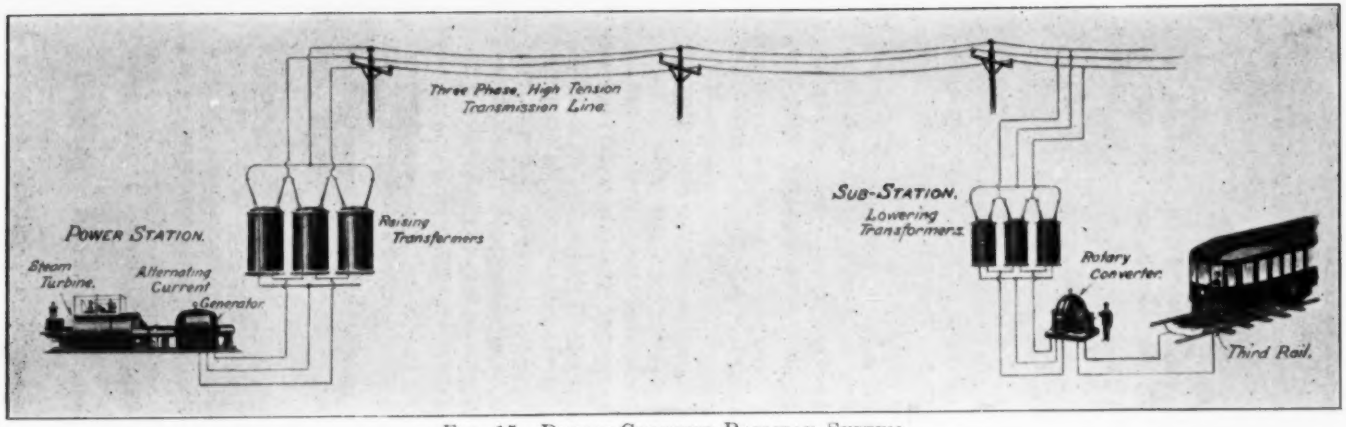


FIG. 15 DIRECT-CURRENT RAILWAY SYSTEM

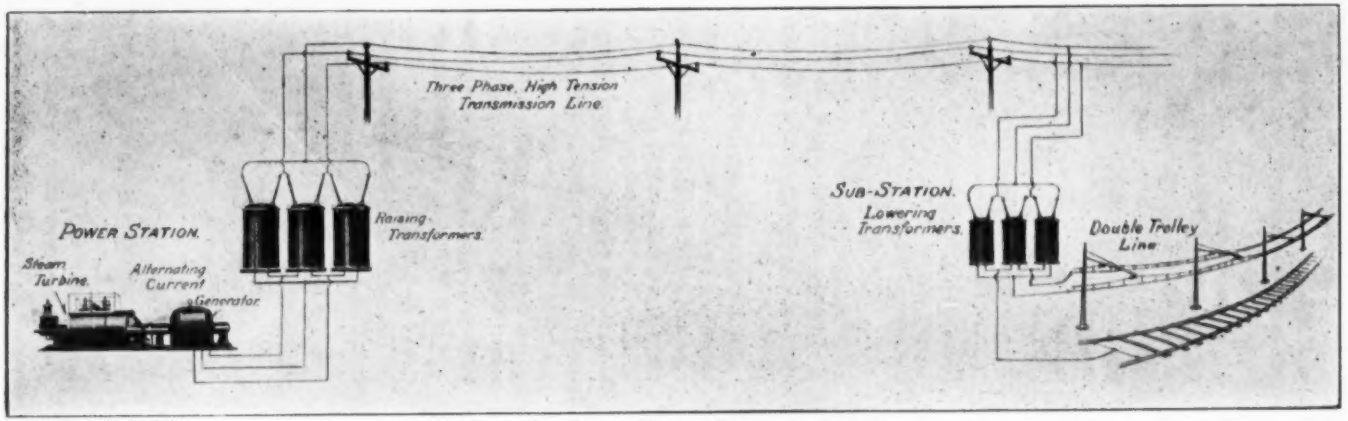


FIG. 16 THREE-PHASE RAILWAY SYSTEM

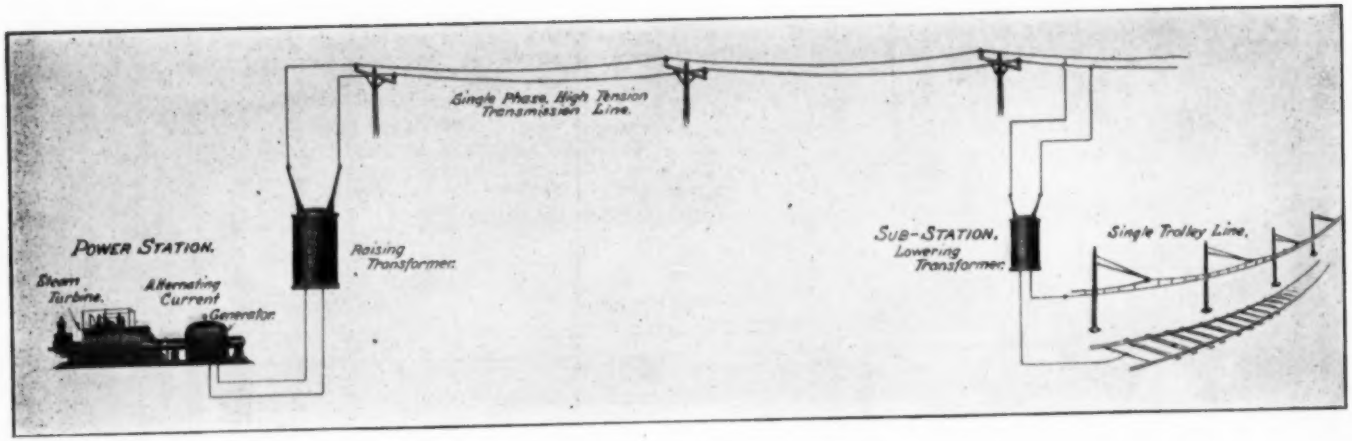


FIG. 17 SINGLE-PHASE RAILWAY SYSTEM

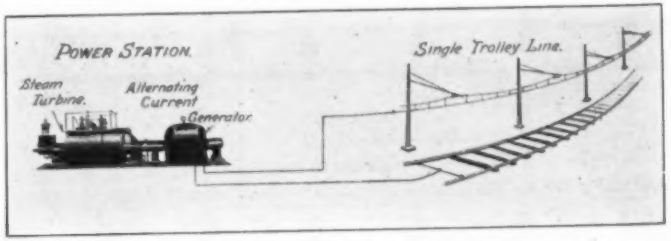


FIG. 18 SINGLE-PHASE RAILWAY WITHOUT TRANSMISSION SYSTEM

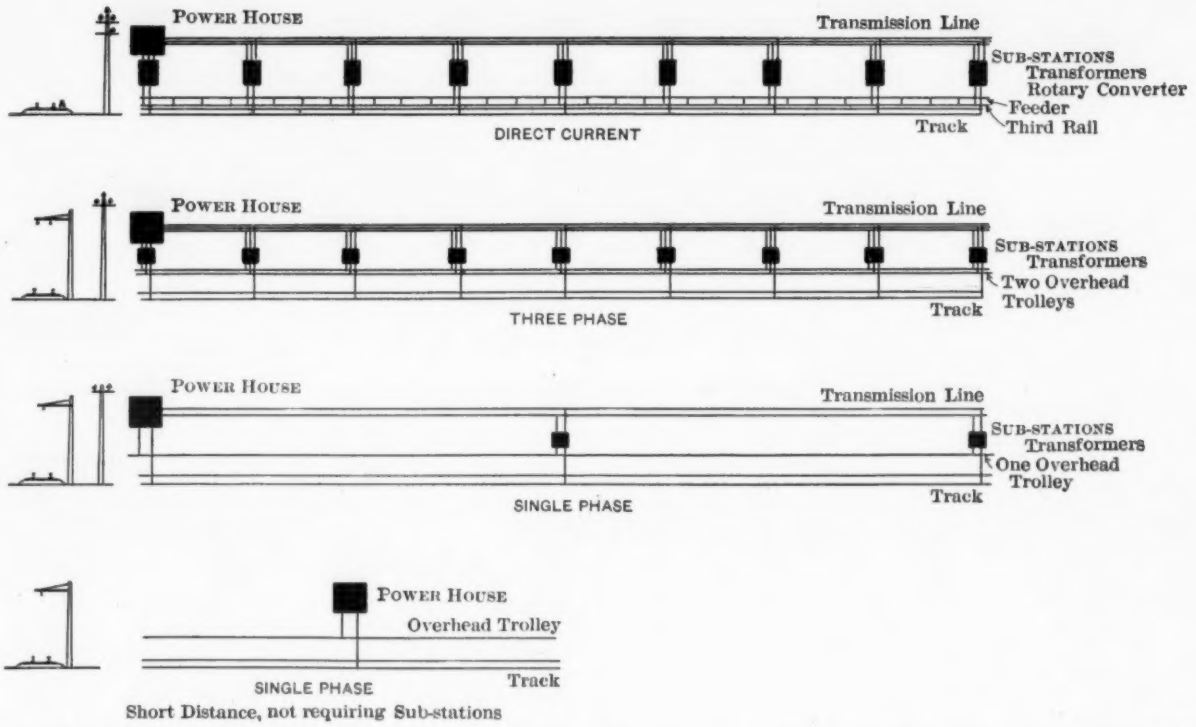


FIG. 19 ELECTRIC RAILWAY SYSTEMS. DIAGRAMS SHOWING TRANSMISSION CIRCUITS, SUB-STATIONS AND CONTACT CIRCUITS BETWEEN POWER HOUSE AND LOCOMOTIVES CORRESPONDING TO SKETCHES IN FIGS. 15 TO 18

318 The loss between power station and the locomotives is represented by the upper shaded areas. The respective losses in raising transformers, transmission line, lowering transformers, rotary converters and the contact line (comprising trolley or third rail with track return) are segregated.

319 It will be noted that the large losses in the rotary converters appear only in the direct current system. The larger single-phase column shows the losses where the distances are such that it is necessary to use a transmission line and transformers. The smaller single-phase column represents the trolley wires connected to the generators without any intervening transmission line or transformers. The loss of power between power house and locomotives is relatively

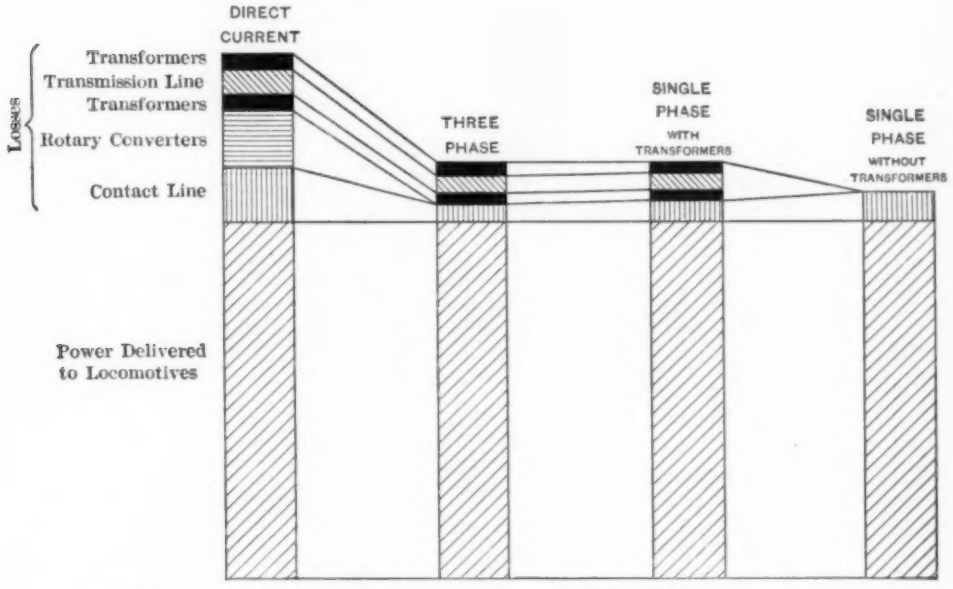


FIG. 20 SHOWING COMPARATIVE LOSSES BETWEEN POWER HOUSE AND LOCOMOTIVES

small as compared with that in any of the other systems. This is the condition on the New York, New Haven & Hartford Railroad, where the power house is distant nearly 20 miles from one end of the line.

COMPARATIVE FIRST COSTS, SHOWN IN FIG. 21

320 Fig. 21 shows the comparative estimates prepared a few months ago of first cost in a particular case for electrification by the direct-current system and by the single-phase system. In the preparation of these estimates the three-phase system was not called for and as no estimate covering it has been prepared, it is not included in the present comparison. The estimates cover a single track line 100 miles long involving both freight and passenger traffic in both through and local service and include twenty locomotives.

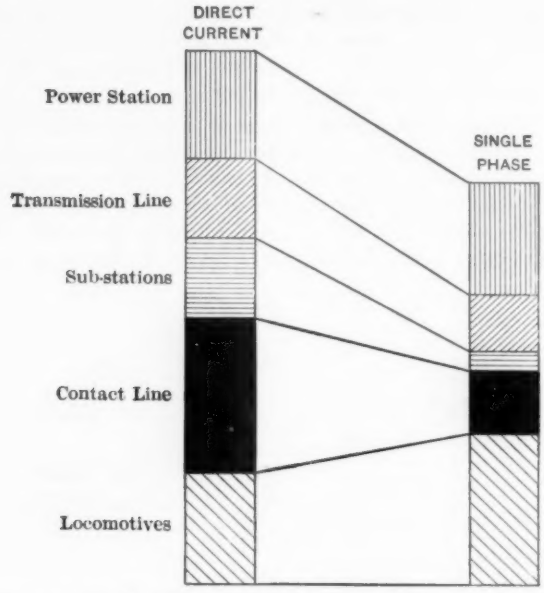


FIG. 21 COMPARATIVE FIRST COSTS FOR DIRECT-CURRENT AND SINGLE-PHASE SYSTEMS IN A PARTICULAR CASE OF 100-MILE SERVICE

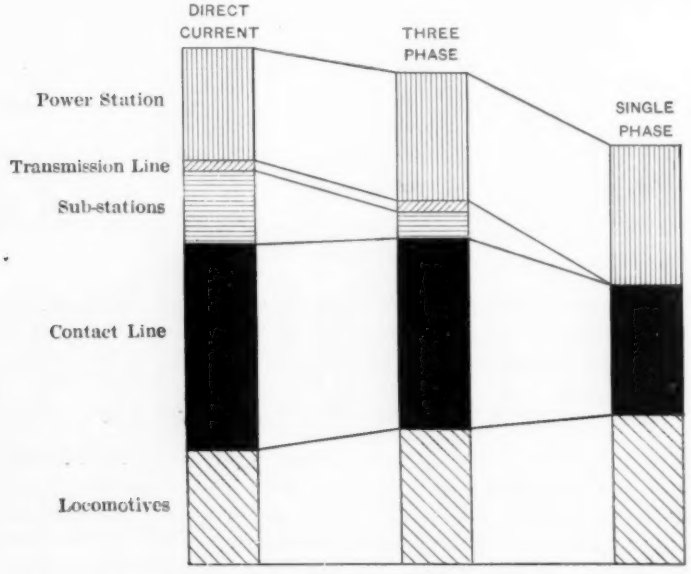


FIG. 22 COMPARATIVE FIRST COSTS IN THE DIFFERENT SYSTEMS FOR A SPECIAL CASE OF PUSHER SERVICE

321 The costs for power station include only the machinery and building and do not include cost of hydraulic development. It will be noted that the considerably less cost of the single-phase system in this case is due largely to the lower cost of contact line and sub-stations.

COMPARATIVE FIRST COSTS, SHOWN IN FIG. 22

322 Fig. 22 shows the comparative estimates of first cost for the three systems for pusher service on mountain grades in a particular case involving the use of twelve locomotives. The total length of line is 32 miles, part of which is single track, part double track and part three tracks. In addition to the main line there is a large yard to be electrified, there being a total of 90 miles of single track. The location of the power station was fixed by non-electrical considerations.

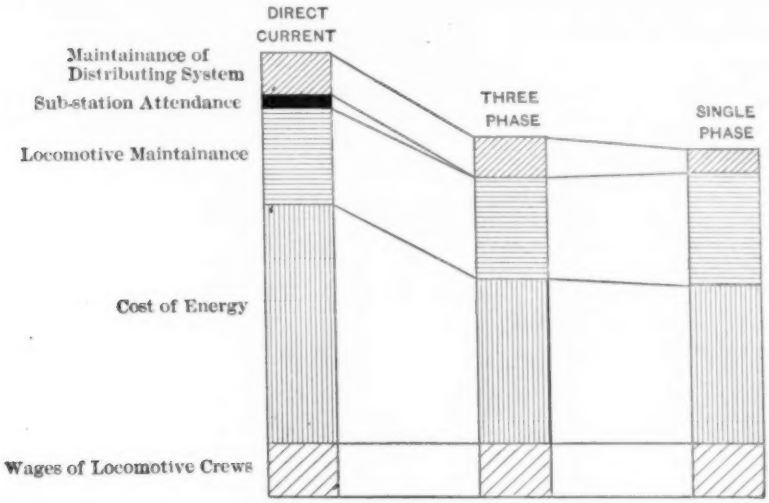


FIG. 23 COMPARATIVE OPERATING COSTS IN THE DIFFERENT SYSTEMS IN A SPECIAL CASE OF PUSHER SERVICE

The distances were such that sub-stations were required when either direct current or three-phase current was assumed, but the entire system could be fed direct from the generators if single-phase current was used.

323 It will be noted that in this case the omission of sub-stations and transmission effects a very considerable saving in favor of single-phase as well as the usual large saving in cost of contact line effected by the use of this system. The cost of the part of the system between the power house and the locomotives in the direct-current system is nearly equal to the cost of both power house and locomotives. On the other hand, the cost of the single-phase contact line, the only intervening element between the power house and the locomotives, is less than one-half of the cost of the direct current transmission and contact system.

COMPARATIVE OPERATING COSTS, SHOWN IN FIG. 23

324 Fig. 23 shows comparative operating costs for the three systems for the pusher service outlined in the preceding diagram of first costs. It should be noted

that these costs do not include fixed charges. If fixed charges were included the difference in operating costs in favor of the single-phase system would be much more marked.

325 In connection with this diagram it should be noted that sub-station attendance is required for the direct current system only. The reason for the three-phase and single-phase systems being so nearly on a par is that this case is an ideal one for the application of the three-phase system since it involves constant-speed operation under constant-load conditions. It is notable, however, that even under these conditions the single-phase system shows somewhat lower operating costs than the three-phase system.

326 The high operating cost with the direct-current system is seen to be due largely to the greater amount of power required for operation by this system on account of the large losses which occur between the power house and the locomotive in this system.

APPENDIX NO. 4

ELECTRIFIED STEAM ROADS AND ELECTRIC ROADS FOR TRUNK LINE SERVICE

The accompanying tables give data upon many of the important railroads on which electricity is used in heavy railway service. Only such data are included as were conveniently available and such omissions or inaccuracies as may occur do not detract materially from the forceful presentation of the extent and character of the use which is now being made of electricity in railway service.

402 The horsepower ratings of the various motor cars and locomotives are in general the nominal ratings for a short period, usually one hour, but as these ratings have been adapted in some cases to the particular service in which the motors are to operate they cannot be taken as a basis for an accurate comparison between the capacities of different equipments.

TABLE 4 SINGLE-PHASE ELECTRIFICATION
ON STEAM RAILWAYS AND IN TRUNK LINE SERVICE

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	h.p.	No.	h.p.
N. Y., N. H. & H. R.R. Main Line	21	100	11,000	4	600	41 2	1400 1600
New Canaan Br.	8	8	11,000	2	500		
Grand Trunk R.R.	3.5	12	3,300	...	...	6	900
Erie R.R. Rochester Div.	34	34	11,000	6	400	...	....
Colorado Southern Ry. Denver & Interurban	46	46	11,000	8	500	...	....
Baltimore & Annapolis Short Line	25	30	6,600	12	400	...	....
Swedish State Ry.	7	7	3,300 20,000	2	240	1	300
Midland Ry., England	8.5	17	6,600	1 2	300 360	...	....
Prussian State Rys.	16.5	31	6,600	20 42 54	250 400 345	1	1500
London, Brighton & South Coast Ry.	8.6	17.2	6,000	16	460	...	....
Rotterdam-Haag-Scheveningen	20.5	46.5	10,000	19	360	...	....
Spokane & Inland	129	129	6,600	28	400	6 5	500 720
Midi Ry. of France	75	...	12,000	30	500	2	1600

TABLE 5 CONTINUOUS-CURRENT ELECTRIFICATION

ON STEAM RAILWAYS AND IN TRUNK LINE SERVICE

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	h.p.	No.	h.p.
New York Cent. R.R.	33	132	650	137	400	47	2200
Pennsylvania R.R.	20	75	650	180	400	24	4000
West Shore R.R.	44	106	650	20	360	...	....
Long Island RR.	42	125	650	137	400	2	1200
West Jersey & Seashore R.R.	75	150	650	68	400	...	....
B. & O. R.R.	3.7	7.4	600	...	...	2.5 5	1600 1100
Northeastern Railway	37	...	600	...	300	2	600
Mersey Tunnel	4.8	...	600	24	400	...	....
Lancashire & Yorkshire Railway	18	60	600	...	600	...	....
Great Western Ry.	5	...	600	...	600	...	....
Metropolitan Railway	...	67	600	56	600	10	800

TABLE 6 CAR EQUIPMENT OF SUBWAY AND ELEVATED SYSTEMS IN AMERICAN CITIES

THE DIRECT-CURRENT THIRD-RAIL SYSTEM AT APPROXIMATELY 600 VOLTS IS USED IN ALL CASES

ROAD	MILES OF SINGLE TRACK	MOTOR CARS	
		No.	h.p.
Boston Elevated Railway	19	219	320
Brooklyn Rapid Transit	71	558 101	300 400
Interborough Rapid Transit (New York)	190	969 764	250 400
Hudson & Manhattan (New York)	12	140	320
Chicago & Oak Park	19.4	65	320
Metropolitan West Side (Chicago)	51.1	15 210	400 320
Northwestern Elevated (Chicago)	25.5	20 128	250 320
Southside Elevated (Chicago)	36.5	150 70 150	180 150 110
Philadelphia Rapid Transit	11	100	250

TABLE 7 THREE-PHASE ELECTRIFICATION

On Steam Railways and in Trunk Line Service

Road	Miles of Line	Miles of Single Track	Line Voltage	Motor Cars		Locomotives	
				No.	h.p.	No.	h.p.
Gt. Northern R.R.							
Cascade Tunnel.....	4	6	6600	..	..	4	1900
Italian State Railways.							
Valtelina Railway ..	66	...	3000	10	400	2 7	800 1500
Giovi Railway.....	12.4	37.3	3000	..	..	20	2000
Mt. Cenis Tunnel...	4.4	...	3000	..	..	10	2000
Savona Ceva	...	...	3000	..	..	10	2000
Swiss Federal Railways							
Simplon Tunnel.....	13.7	14.3	3000	..	..	2 2	1100 1300
Gergal Santa Fé (Spain)	13.1	14.4	5500	..	..	5	320

APPENDIX NO. 5

THE EARLY HISTORY OF SINGLE-PHASE RAILWAY MOTORS

In Par. 22 brief mention was made of two single-phase motors of 10 h.p. built in 1892 by the Westinghouse Company for determining the possibilities of using alternating current for traction work. These motors were designed for 2000 alternations per minute and about 200 volts. They were of the series type, with commutators, and had a relatively large number of poles. They were mounted

FIG. 24 THE FIRST SINGLE-PHASE ELECTRIC CAR. DESIGNED IN 1892 AND EQUIPPED WITH TWO SINGLE-PHASE SERIES MOTORS

upon a car and tested on a short piece of track with some very short curves and rather steep grades. The car is shown in the accompanying illustration, Fig. 24. The current was supplied from a conductor placed intermediate between the rails. The capacity of the engine and generator used for these tests was insufficient for the service, and the voltage drop in the rails was excessive. The test showed that the motors would run the car, although the current available was hardly

sufficient for operating the car on the curves and grades. A transformer on the car served to transform from a few hundred volts on the supply circuit to that required for the motor. There were several taps on this transformer, and by means of several single-pole switches the voltage could be varied. Several frequencies lower than that for which the motors were designed were employed for testing the motors.

502 Almost the entire effort in railway work at that time was concentrated on electric cars for city service. While the single-phase system gave promise of certain advantages for this service, it was found that there were disadvantages, particularly in the large losses in the conductors for supplying the current, which rendered the single-phase system much less adapted to this service than the direct-current system.

503 It was recognized that the single-phase system would be ideal for locomotive operation, but as there were no such projects then in view, no immediate work was done in building large motors of this type.

504 Some seven or eight years later, the enlarging field of railway operation was showing the imperative need of some practical method by which high tension could be used on the trolley wire in order to minimize the cost of supply circuits. Furthermore, the accrued experience and greater knowledge in the methods of designing alternating-current motors opened the opportunity for the development and perfection of the single-phase system.

505 Motors of 100 h.p. were designed, built and tested on an experimental track. The results of this work and the importance of the single-phase system in railway operation were presented in a paper by Mr. B. G. Lamme before the American Institute of Electrical Engineers in September 1902. This paper awakened widespread interest and was followed by the active development of single-phase apparatus by a number of manufacturing companies, both in America and in Europe. There are now about 60 single-phase railways in operation.

ECONOMICS OF RAILWAY ELECTRIFICATION

By Wm. Bancroft Potter, Schenectady, N. Y.

Member of the Society

National prosperity and importance are largely proportional to facilities for intercommunication, and since overland transportation is to so large an extent dependent on railways any development providing for better railway service is of paramount importance. Steam locomotives and electric motors are the two recognized means of applying power which are available for practical railway requirements. The fundamental principles which underlie the problem of train movement are the same in either instance, but a true comparison of their relative advantages can only be made by a study of each particular method.

2 Much that has been written has treated the subject of electrification of steam railways from the general standpoint of averages, but unfortunately the economic application of electricity is not a subject for generalization—unfortunately, because averages are convenient and usually available, but often lead to erroneous conclusions, either for or against electrification. It is a mistake to assume that the average of the expenses for the entire railroad represents the actual expense for the particular conditions usually existing on the division under consideration.

3 On account of the investment already incurred, and because the question is usually one of determining comparative results, the electrification of an existing steam railway is a more complex problem than the electrical equipment of a new road.

4 Electrification, like any other engineering work, involves an investment against which there will be a fixed charge for interest and a liability of depreciation. The interest is a constant and permanent charge which must be met irrespective of any economy which may be secured by intelligent operation. The subject of depreciation is

The American Society of Mechanical Engineers, 29 West 39th Street, New York, July 1910. All papers are subject to revision.

receiving more attention than formerly, the tendency having been to make the operating expenses cover this charge. However classified, the depreciation charge must be accounted for, and it is directly influenced by the character of the equipment with respect to reliability, durability, and capacity to provide for future requirements.

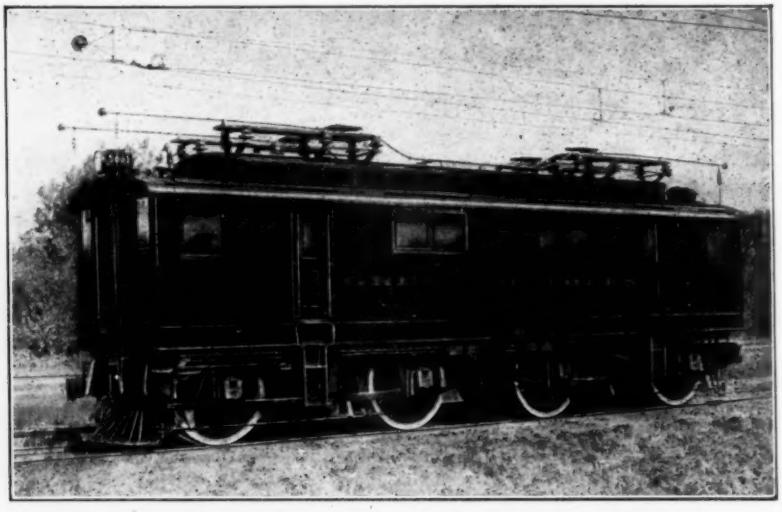


FIG. 1 THREE-PHASE LOCOMOTIVE USED AT THE CASCADE TUNNEL OF THE GREAT NORTHERN RAILWAY

Trolley Voltage	6600
Frequency, cycles	25
Total weight, lb.	230,000
Weight on drivers, lb.	230,000
Maximum rated draw-bar pull	77,000
Continuous rated draw-bar pull	35,000
Speed, mi. per hr.	15

Duty—Three units to haul 1500-ton train up 2.2 per cent grade

5 The utilization of higher trolley potentials, made possible with direct current by the development of the commutating-pole motor, and with alternating current by the development of the single-phase motor; the higher speeds of rotary apparatus in the sub-stations; and the development of the steam turbine, have effected a material reduction in the investment required and the cost of operation.

6 The different methods of electrification applicable in any instance should be carefully analyzed with regard to interest, depreciation and operating expense, and only the net result should be

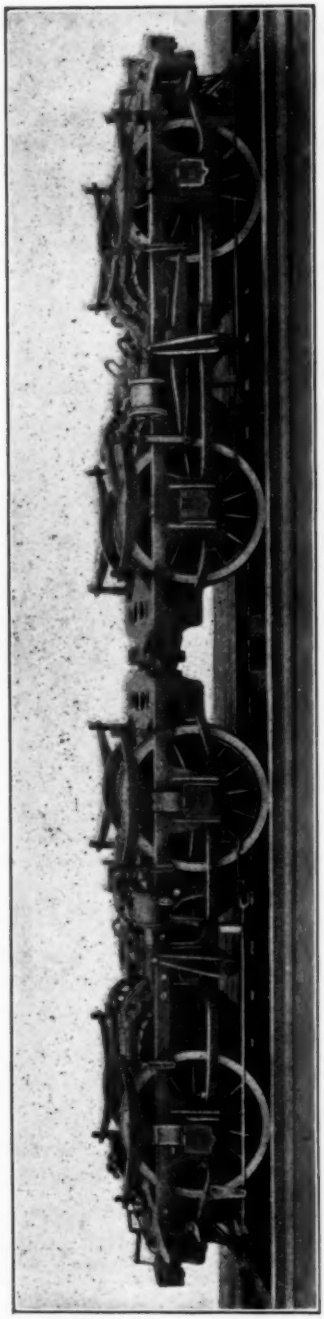


FIG. 2 TRUCKS FOR THREE-PHASE LOCOMOTIVE, GREAT NORTHERN RAILWAY

given consideration in determining the class of equipment. In this connection it is well to bear in mind that the expenditure is a lump sum which can be accurately determined, while depreciation and operating expense can only be approximated. Reference to the corresponding items of expense on railways operating under conditions comparable to those of the line to be electrified, will supply the most reliable figures. Future traffic developments must not be overlooked and the type of initial electrification should be selected with due regard to the ultimate requirements.

7 There would undoubtedly be an advantage in having the character of the energy supplied to the contact conductor uniform, but this is out of the question on account of the great difference in the requirements of specific conditions, such as congested urban or suburban service and comparatively infrequent trunk line train movements.

8 The sub-station and rolling stock may be equipped for operation with direct current or alternating current, single-phase or three-phase, and what is commonly spoken of as "the system" usually refers only to that part of the general scheme of electrification which comprises the sub-station and rolling stock equipment. There are exceptional

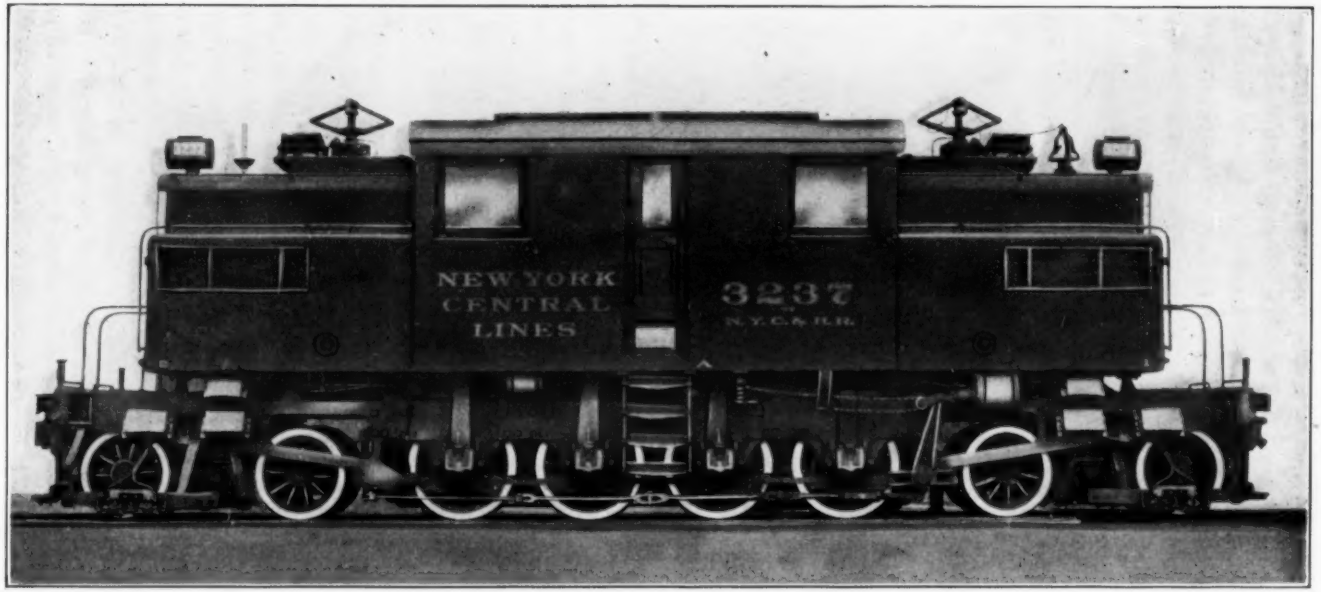


FIG. 3 DIRECT-CURRENT LOCOMOTIVE USED IN THE NEW YORK CENTRAL ELECTRIFICATION AT NEW YORK

Voltage	660, D. C.
Total weight	230,000
Weight on drivers, lb	141,000
Maximum rated draw bar pull, lb	47,000
Continuous rated tractive effort, lb	7,250
Speed, mi. per hr	60

cases where the power station and transmission lines have direct relation to the rolling stock equipments; but with the development of alternating-current transmission, this is less frequently the case than it was a number of years ago when 600-volt power stations supplied power directly for the operation of 600-volt motors.

9 The development of apparatus for higher voltage direct current has so far increased its scope that direct current at either 600 voltage or higher may be considered the most economical for city and interurban service, and for the electrification of steam railways where the density of traffic is sufficient to require a relatively large

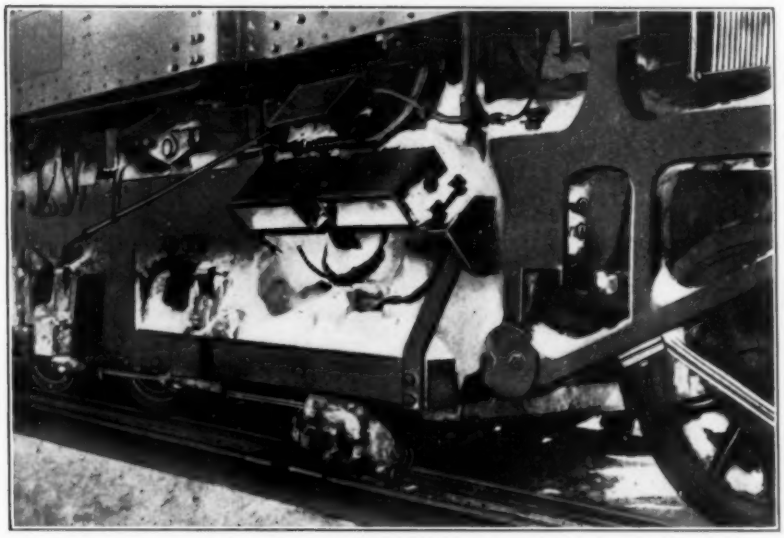


FIG. 4 PORTION OF A NEW YORK CENTRAL LOCOMOTIVE AFTER RUNNING THROUGH SNOW

investment for rolling stock, as compared with that required for the secondary distribution system and the sub-station apparatus.

10 Single-phase and three-phase rolling stock equipments are applicable only to exceptional conditions. The reason for this is the greater first cost of such equipments. This is especially true when comparing single-phase with direct-current. The type of equipment used on the rolling stock may well be a more important factor in the economy of investment and operation than the scheme of power distribution.

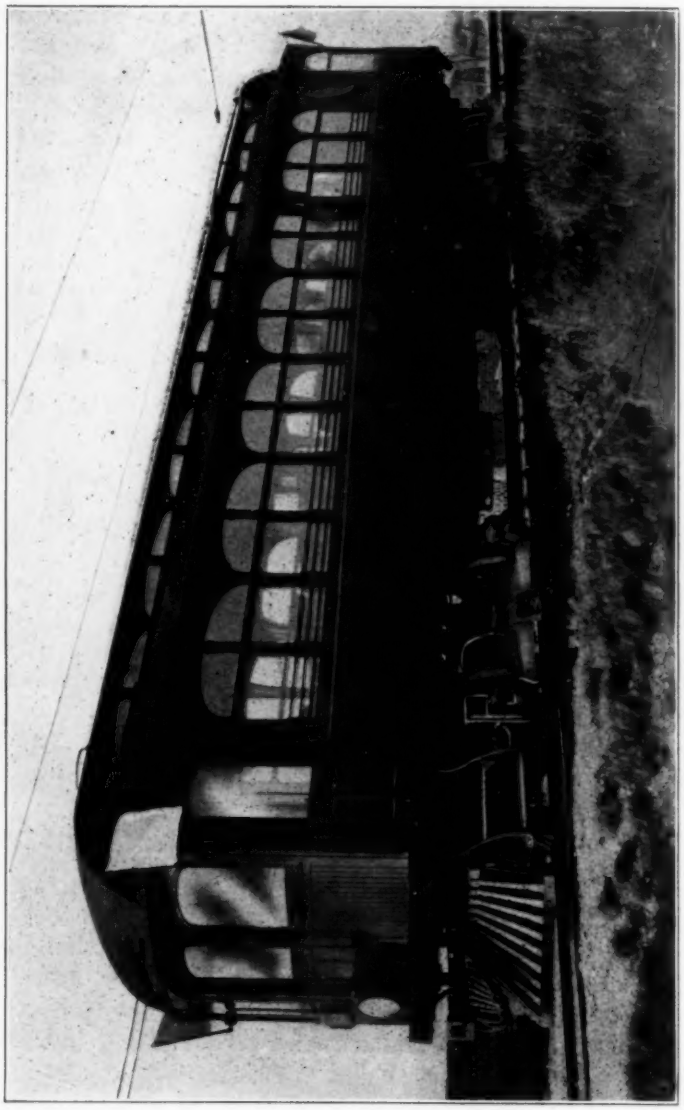


FIG. 5 TYPICAL AMERICAN INTERURBAN CAR, WEST SHORE RAILROAD

11 Under the conditions which exist in America, direct-current and single-phase are applicable to either level or grade work; while three-phase will probably be limited to the latter where its regenerative feature of returning energy to the line may be of value. The relative economy of the different systems of electrification is dependent on the density of traffic and the character of power available, rather than on the length of the railway.

12 In cases where purchased power is used, or is depended on as a reserve, the frequency of the current supplied by the power company will have a bearing on the cost of sub-stations, and will thus affect the choice of the system. For direct-current operation,

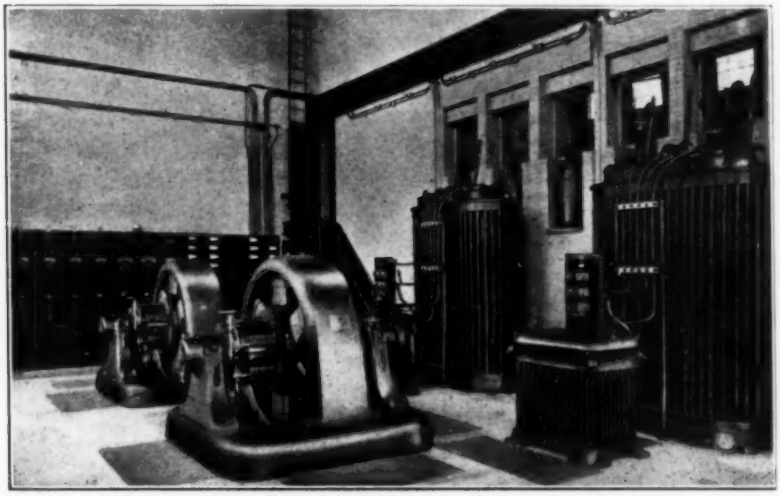


FIG. 6 INTERIOR OF 60,000-VOLT INTERURBAN SUB-STATION, CLARKS MILLS, N. Y.

rotary apparatus is used for converting the alternating into direct current, and the frequency of the supply is therefore relatively unimportant. For single-phase operation under the usual conditions, a frequency of not more than 15 cycles is desirable; and to provide this frequency, rotary frequency-changers are as necessary as are rotary converters in the case of direct current, since the frequency of existing power companies ranges from 25 to 60 cycles.

13 With power supplied at the proper frequency for single-phase operation, permitting the use of static transformers and dispensing with frequency changers, the amount of energy required for a given

trunk line service is in many cases nearly the same as for direct current, the greater weight of the equipped rolling stock, and the lower efficiency of the single-phase equipments, offsetting the rotary converters and trolley-line or third-rail losses of the direct current.

TABLE 1 REASONABLE VALUES FOR TRUNK LINE SERVICE

SUB-STATIONS

	600 v. D. C.	1200 v. D. C.	11,000 v. 1-Phase	11,000 v. 3-Phase
First cost per kw., complete	$26	$28	$11	$12
Comparison of installed kw., %	200–250	100–125	100	100–125
Load factor, machines in service, %	20–40	35–70	40–80	30–60
Average efficiency, %	78–88	87–92	97–98	97–98
Yearly operation and maintenance, each station	$5000	$5000	$2500	$2500

CONTACT CONDUCTORS[1]

	Third Rail		Overhead	
First cost, per mile	$5000 to $7000	$5500 to $7500	$3500 to $7000	$4500 to $8000
Efficiency, %	88–92	90–96	93–97	93–97
Maintenance per mile per year	$75–$125	$100–$150	$100–$200	$125–$250

ROLLING STOCK[2]

	600 v. D. C.	1200 v. D. C.	11,000 v. 1-Phase	11,000 v. 3-Phase
LOCOMOTIVES				
First cost, each	$44,000	$47,500	$64,000	$58,000
Weight, tons (2000 lb.)	125	125	160	160
Average efficiency, locomotive wheels to trolley, %	85	85	79	81
Maintenance per locomotive per mile, cents	4	4	8	5
MOTOR CARS (COMPLETE)				
First cost, each	$12,000	$13,500	$20,000	.....
Weight, tons (2000 lb.)	43	44	54	.....
Average efficiency, wheels to trolley	82	81	73	.....
Maintenance per car mile, cents	2	2.2	3.5	.....

[1] Variation in cost of third rail due to different weights of rail which may be required. Variation in cost of overhead due to variation in the class of construction, such as with wooden poles or with steel bridges.

[2] Other weights of locomotives will cost more or less about in proportion to their weights. With gearless direct-current locomotives, the average efficiency of locomotive wheels to trolley is approximately 88 per cent.

CONDITIONS DETERMINING RAILWAY EQUIPMENT

14 The principal conditions which determine railway equipment are:

DATA SHEET

a Profile of road.
b Transportation required, *i.e.*, weight of trains or seating capacity of cars.
c Frequency of trains.
d Length of individual runs or distance between stops.
e Schedule required.
f Length of railway to be electrified.

15 In the selection of the electrical system best adapted to a particular set of conditions there are three items to be considered: (*a*) sub-stations, (*b*) contact conductors, (*c*) rolling stock. A comparison of these items determines the relative economic values of the systems. There are certain features under each of these items which may properly be examined. For trunk line service the values in Table 1 will be found within reasonable limits for the usual requirements.

16 We will consider briefly the effect of changes in the Data Sheet items (Par. 14):

a Profile: From a level country to a limiting grade of 1 or 1½ per cent there will be little difference in the relative values of the systems. With steeper grades the conditions will be more favorable for alternating current.

b Traffic Requirements: Heavy individual train units favor the alternating-current system with exception of the locomotives; light trains or multiple-unit operation favor the direct-current system.

c Frequency of Trains: Infrequent service with a relatively small number of locomotives favors the alternating-current, frequent service the direct-current. With increase in number of trains, the direct-current systems gain relatively faster than the alternating-current in economy of operation, due to relatively decreased sub-station operation, increased sub-station efficiency, and lower cost of equipment maintenance. It is therefore well to consider what the ultimate traffic density may be and select the system best suited to meet these requirements.

d, e Distance between Stops and Schedule Required: Variations in these will not affect the relative value of systems unless extreme requirements, such as high schedule speed with short runs, make the use of direct current imperative.

f Length of Road: For a similar character of service throughout, the railroad may be of any length without affecting the relative desirability of the various systems. What is suitable for the first fifty miles will be equally suitable for any extension.

An examination of these variables will show that a change in the conditions to be met will radically change the relative economic value of the systems of electrification.

17 The single-phase system, by reason of the apparent simplicity of its elements and the utilization of higher potential for the contact conductor than is possible with direct current, is admittedly very attractive. There is the other side of the question, that it is impossible to build a single-phase commutating motor comparable in first cost and maintenance with a direct-current motor. Over this subject of alternating-current single-phase vs. direct-current systems there has been a great deal of controversy. It is our opinion that comparative results obtained up to the present time are in favor of direct-current.

18 Desirable as would be a standard system for all classes of service, we cannot hope to establish such a standard should it impose an additional expense without adequate return. A summing up of all the elements of each electrical system will generally lead to a definite showing of which system is most desirable to meet specific conditions. For trunk line service a higher potential than 600 volts will unquestionably be used; 1200 volts direct-current will prove economical in some cases, but a still higher voltage is required to provide economically for the heavier intermittent service. Whether this potential will be 1800 or 2400 volts direct-current or 11,000 volts alternating-current cannot be settled arbitrarily.

INTERURBAN RAILWAYS

19 Let us consider the interurban railway situation in the United States, particularly in regard to the various available schemes of electrification. These are, 600-volt direct-current, 1200-volt direct-

current, and single-phase, the three-phase being debarred on account of the complications of the necessary double overhead-distribution system.

20 The application of single-phase to new projects has been practically abandoned, there having been but one or two new installa-

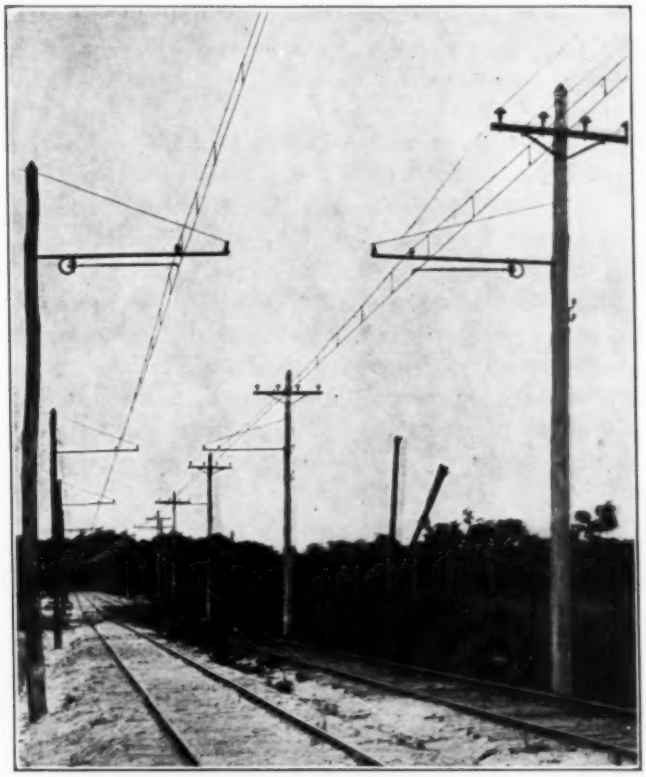


FIG. 7 TYPICAL AMERICAN OVERHEAD 6600-VOLT SINGLE-PHASE INTERURBAN TROLLEY LINE, BALTIMORE & ANNAPOLIS SHORT LINE, ANNAPOLIS, MD.

tions in the last three years. This arrested development of a system which for a short time held forth considerable promise, has been brought about by a general recognition of its limitations. Experience has shown these to be:

a Excessive weight of rolling stock.
b Excessive cost of rolling stock.

c High cost of equipment maintenance.
d Increased power consumption.
e Rapid depreciation of motor.
f Rapid depreciation of car bodies and trucks.
g Increased cost of maintaining track and road-way.

Moreover it is recognized that any interurban road in the United States must be capable of operating over existing city tracks from 600-volt direct-current trolley, a condition which hampers the single-phase system on account of increased complications in the control system.

21 For interurban railways a potential of 1200-volt direct-current has been selected, because with the motors wound for 600 volts the car may be operated at the same speed from either 600 or 1200-volt trolley, by connecting the motors all in parallel for 600-volt operation, and two in series with two groups in parallel on a 1200-volt section.

22 To show clearly the relative merits of the systems we have made an analysis of an interurban railroad 100 miles long with cars in each direction every hour. This condition represents practically the minimum car requirements in the United States, and is therefore favorable to the single-phase. It is obvious that any increase in traffic density will be relatively more favorable to the direct-current system on account of the lower first cost of cars, lower car maintenance and relatively lower cost of sub-station operation.

23 Assume a typical interurban condition:

a Profile: rolling country.
b Transportation required: passenger cars to seat 50 passengers and having baggage compartment, or the equivalent of 60 passengers without baggage compartment.
c Frequency of trains: one every hour in each direction.
d Average distance between stops: 3 miles.
e Schedule speed: 33 miles per hour.
f Length of road: 100 miles.
g To operate on existing 600-volt city tracks.

The general data required are approximated in Tables 2 to 7.

24 There will be an additional cost of operation and maintenance with the single-phase system for the items of track and roadway, due to additional weight of cars, car shop expenses in providing greater facilities for shop inspection and repairs, and greater skill in superintendence of equipment. In a number of instances this

has been found to amount to several cents per car mile. A conservative estimate would require at least one cent per car mile to be added for these items.

25 The comparison in Table 7 brings out the fact that even for conditions selected as favorable to the single-phase system, the 600-

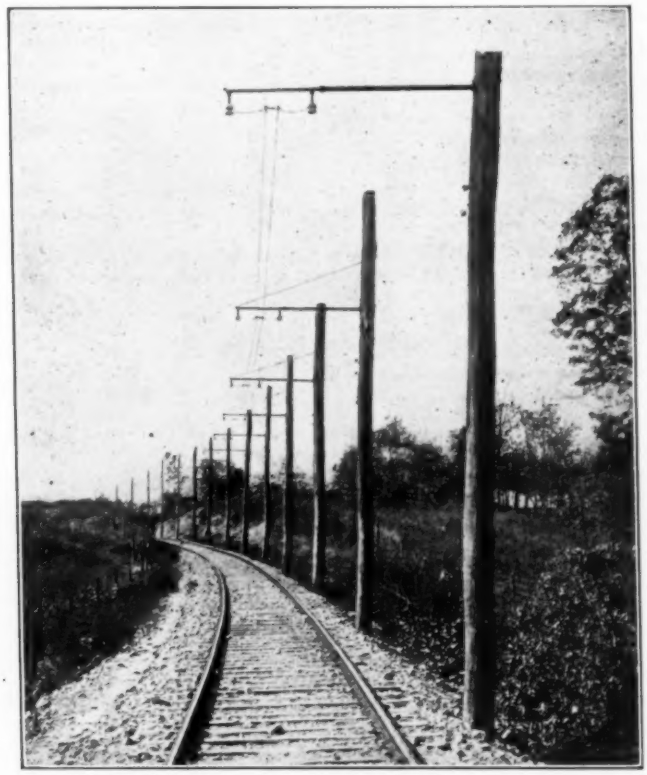


FIG. 8 1200-VOLT DIRECT-CURRENT OVERHEAD-LINE CONSTRUCTION OF THE PITTSBURG, HARMONY, BUTLER & NEW CASTLE RAILWAY, PITTSBURG, PA.

volt direct-current system is the more economical considering operation, maintenance and fixed charges. An examination of the elements which enter into the first cost and operation of a system will show at once that as the density of traffic increases there is a rapid gain in the relative advantage of the direct-current over the single-phase system.

TABLES RELATING TO TYPICAL INTERURBAN ELECTRIC SERVICE

TABLE 2 GENERAL DATA FOR CARS

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Number of cars	15	15	18
Seating capacity, passengers	60	60	60
Distance between stops, miles	3	3	3
Schedule speed, miles per hour	33	33	33
Maximum speed, miles per hour	48	48	55
Weight each car, tons (2000 lb.)	35	36	43
Car miles per day	3000	3000	3000
Miles per car in service per day	300	300	300
Miles per car per day, average[1]	200	200	166
Estimated maintenance per car mile, cents.			
a Electrical	0.70	0.77	1.50
b Mechanical	1.00	1.00	1.25
Total car barn expense	1.70	1.77	2.75
Amperes starting car	520	280	75
Amperes running car	174	94	24
Kilowatt hours per car mile at car	2.8	2.88	3.78
Cost each car complete	$10,000	$11,500	$17,000

TABLE 3 SUB-STATIONS

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Number of sub-stations	9	4	2
Estimated momentary demand			
Cars starting	1	1	2
Cars running	1	1	0
Peak load, kilowatts	416	448	670
Average load, each sub-station, kilowatts	52	120	275
Size each unit, kilowatts	300	300	300
Number of units	2	2	3
Load factor (machines in service)	0.17	0.40	0.46
Average efficiency	0.76	0.87	0.96
Cost each sub-station complete	$24,000	$26,400	$10,000

[1] On twelve American single-phase interurban roads the average miles per day called for on the published time tables, divided by the number of cars owned, is 138; on four 1200-volt roads which have been operating over a year this number is 237, the larger number of alternating-current cars being required on account of the fact that a greater number are necessarily held in the barn for inspection and maintenance purposes. This explains why in the table above 18 alternating-current cars are assumed and 15 direct-current cars.

TABLE 4 FEEDER COPPER REQUIREMENTS

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Maximum momentary demand midway between sub-stations.			
Cars starting	1	1	2
Cars running	0	1	0
Amperes	520	374	150
Distance between sub-stations	11.8	28	66.6
Equivalent stub-end feed	2.9	7	16.6
Feeder required additional to 4/0 trolley	4/0	1/0	none
Cost overhead construction per mile, including both trolley and feeder	$2300	$2100	$1900

Bonding taken as $400 per mile of track.

Transmission line taken in each case as $840 per mile of track and assumed to run entire length of right of way.

Power house: No power house is included, but it is assumed that power is purchased at the power station bus at one cent per kw.-hr. and fed at any convenient point into the transmission line.

TABLE 5 POWER CONSUMPTION

	600 v. D. C.	1200 v. D. C.	6600 v. A.C.
Total kilowatt-hours per day at cars	8400	8650	11,400
Efficiency, secondary distribution	0.90	0.90	0.94
Sub-stations	0.76	0.87	0.96
Transmission line and power house step-up transformers	0.94	0.94	0.94
Combined efficiency	0.64	0.74	0.85
Kilowatt-hours per day at power house	13,100	11,700	13,400

TABLE 6 SUMMARY OF COSTS

First Costs

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Transmission	$ 84,000	$ 84,000	$ 84,000
Sub-stations	216,000	106,000	20,000
Secondary distribution	230,000	210,000	190,000
Bonding	40,000	40,000	40,000
Cars	150,000	172,500	360,000
Total	$720,000	$612,500	$694,000

ANNUAL FIXED CHARGES

DEPRECIATION	Life Years	Annuity 5%	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Transmission	20	30.34	$ 2,500	$ 2,500	$ 2,500
Sub-stations	20	30.34	6,500	3,200	600
Secondary distribution	15	46.34	10,600	9,700	8,800
Bonding	10	79.50	3,200	3,200	3,200
Cars (A. C.)	12	62.83	.....	.....	22,600
Cars (D. C.)	15	46.34	6,900	8,000	.....
Total Depreciation			$29,700	$26,600	$37,700
INTEREST AND TAXES					
Interest 5%, taxes 1.5% of cost of electrical material			$46,000	$39,800	$45,000
INSURANCE					
1.5% of sub-station and car costs			$ 5,500	$ 4,200	$ 5,700
Total fixed charges			$81,200	$70,600	$88,400

ANNUAL OPERATION AND MAINTENANCE

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
Transmission	$ 3,500	$ 3,500	$ 3,500
Sub-stations	17,000	7,600	500
Secondary distribution, including bonds	9,000	9,000	10,000
Cars	18,500	19,500	30,100
Power at one cent per kw.-hr	47,800	42,700	49,000
Additional cost maintenance of track and roadway, shops and supervision, due to heavier cars and more expert supervision required for the single-phase	.....	.....	10,900
Total	$95,800	$82,300	$104,000

TABLE 7 COMPARISON OF COST OF SYSTEMS

	600 v. D. C.	1200 v. D. C.	6600 v. A. C.
1 First cost	$710,000	$612,500	$694,000
2 Fixed charges	$ 81,200	$ 70,600	$ 88,400
3 Operation and maintenance	95,800	82,300	104,000
4 Annual cost (Item 2 plus Item 3)	$176,000	$152,900	$192,400
Based on 1,095,000 car miles per year, additional annual charge per car mile above the cost for 1200 volts, in cents	2.1	0	3.6

CONCLUSION

26 The saving effected by the 1200-volt direct-current system is so marked that a great increase in the adoption of this potential for this class of interurban railroading may be anticipated, and on the other hand it will not be surprising if the single-phase interurban system is entirely discarded in America, unless some marked improvement is made in the art and a more economical equipment made available. There is no question regarding the mere movement of trains by any particular system—this may be taken for granted. The study of electrification is really a problem in economic engineering and not simply a technical problem.

27 Reliability of operation is of the greatest importance, not only to the public but to the operating company, and in this respect the electric motor with its simpler construction, even though the general service is supplied from a central power station, has proved its superiority over the steam locomotive. Except in the case of some extraordinary accident, the power station, sub-stations and transmission line, in their entirety, are rarely rendered inoperative. The liability to interruption is principally centered in the equipment of the rolling stock, and for this reason the mechanical and electrical design of the motors, control and equipment devices, should receive careful consideration.

28 The electrical equipment of motor cars and locomotive is exposed to a large extent to dirt, water and snow, and not being particularly convenient for inspection, it usually receives less attention than the apparatus in the power station and sub-stations. It is the custom on many roads to give the equipments a regular inspection once in a thousand or fifteen hundred miles, depending on experience, and to dismantle them for a thorough overhauling once a year. The character of the rolling stock equipment is a factor of far more importance to the reliability of the service than is often appreciated.

29 The steam locomotive has been brought to its present state of development through many years of experience. It is an exponent of the highest type of mechanical design, and notwithstanding its limitations, is remarkably efficient as a source of power. During the past twenty years the power of the steam locomotive has been practically doubled, but the demand today is for still greater power.

30 The multiple-unit idea, to which electric service is so well adapted, was utilized in the design of the Mallet type of steam locomotive where the driving engines of two practically separate

locomotives are supplied with steam from a single boiler. Mallet locomotives have been built having a weight of 441,000 lb. on the drivers, the boiler having over 5800 sq. ft. of heating surface and a grate area of 100 sq. ft. To fire properly a locomotive of this capacity is difficult, and unlike the electric locomotive, its effectiveness depends on the steam from its own particular boiler.

31 With existing road clearances the steam locomotive unit, controlled by a single engineer, seems to have reached nearly the limit of power. The power of a steam locomotive being limited by the capacity of its boiler, an increase in speed can be secured only by a proportional reduction in tractive force. The electric locomotive, on the other hand, is supplied with practically unlimited power from an independent power station, and can maintain a speed and tractive force that would be impracticable with a steam locomotive. The application of electric locomotives to passenger and freight service will result in faster schedules with equal or even heavier trains than are at present handled by steam locomotives.

32 Since the electric locomotive is equipped with a number of independent motor units, controlled by one engineer from a single master controller, it makes no difference, considering the complete locomotive as a machine, whether it be built as a single unit, or as two or three units having the same total weight on the drivers. For convenience in operation and repairs, it is probable that a single electric locomotive unit will be limited to a weight between 200,000 and 300,000 lb. on the drivers, even when built for the heaviest service. There are electric locomotives now under consideration which as single units will exert a maximum tractive effort of 90,000 lb., and which will be capable of maintaining a tractive effort of 35,000 lb. at a speed of 30 miles per hour.

33 Many of the terminal and tunnel electrifications have been brought about from the desire to do away with the danger and nuisance caused by smoke and gas. The elimination of smoke has also an economic aspect in the electrification of terminal stations, in permitting material improvement in the character and value of railway buildings. The Quai d'Orsay terminal of the Paris-Orleans Railway in Paris, which has been in operation since May 1900, was the first instance where a steam railway profited by this feature of electrification.

34 The enhanced value of railway buildings is seen to a marked degree when terminals are electrified in large cities in which land values are high. The fact that electric operation will permit platforms

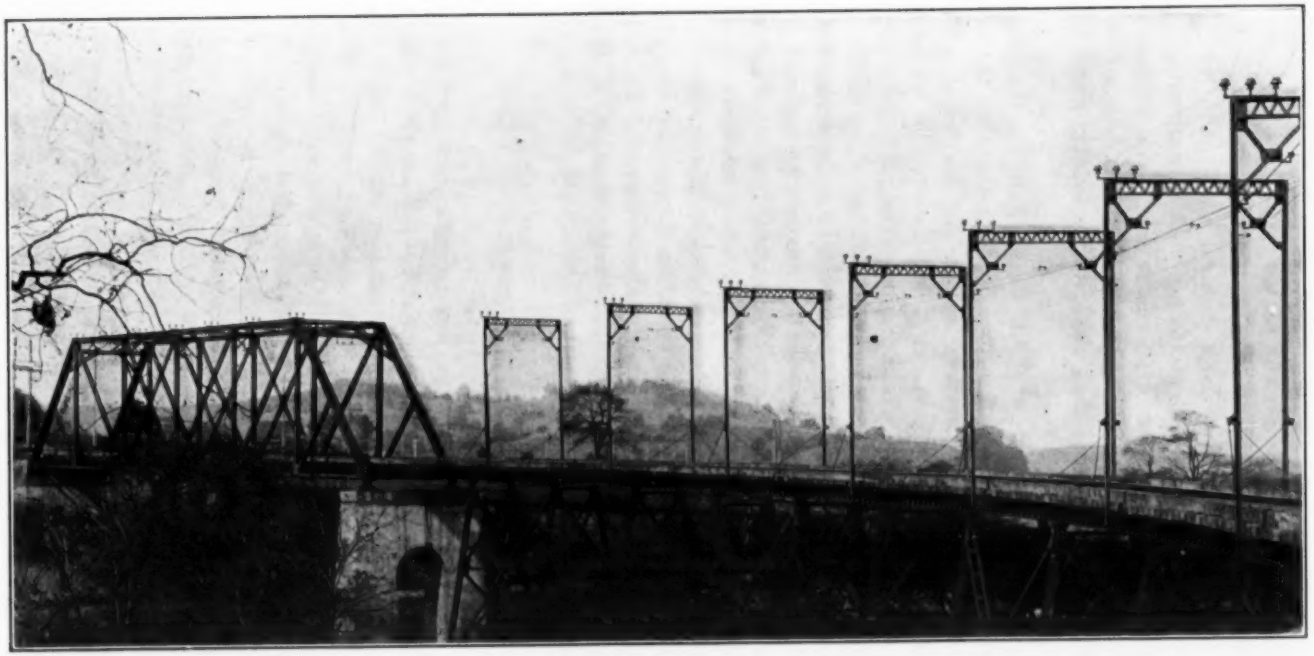


FIG. 9 1200-VOLT OVERHEAD LINE CONSTRUCTION ON STEEL TRESTLE, PITTSBURG, HARMONY, BUTLER & NEW CASTLE RAILWAY, PITTSBURG, PA.

on two or more levels adds greatly to the capacity of the station, or conversely, decreases the land area required for given traffic facilities. In the case of the New York Central terminal in New York City, there will be two levels of platforms, the entire suburban facilities being placed below those of the main line. The Pennsylvania terminal in New York is another instance of station design affording facilities for handling traffic that would be impossible under steam operation.

35 The electric locomotive is well adapted for the handling of trains where the character of the service will not permit the operation of individually equipped cars. Where the service is self-contained, individually equipped motor cars, operated in trains with multiple-unit control, are recognized as providing for the most efficient handling of traffic.

36 Economy in operation will be secured by proportioning the number of cars in a train to the traffic required during different hours of the day. The patronage on which the gross receipts depend will be much encouraged by providing a service with short intervals between trains. In the study of any scheme of transportation, due regard should be given not only to economical operation but also to the method of handling which will insure the maximum gross receipts.

37 The author desires to express his thanks to Mr. C. E. Eveleth for his assistance in the preparation of this paper.

HANDLING LOCOMOTIVES AT TERMINALS

By Frederic M. Whyte, New York

Member of the Society

INTRODUCTION

Detail methods in the handling of locomotive terminals vary so widely that the scope of this paper has been limited to well established practices along certain definite lines, in the United States and Canada, with some personal suggestions. Steam locomotive terminals alone are sufficiently developed to permit of extended discussion.

2 Terminals differ very much in importance and the paper will be confined largely to the more important ones, leaving it to the judgment of the reader to decide what parts apply to the smaller terminals. By the designation "important terminals" is meant those caring for about 100 locomotives during each 24 hours.

LOCATION OF TERMINALS

3 Starting with a terminal at each end of a railroad the intermediate terminals are located as the topography of the line, the location of important towns, or other factors, may indicate. Some years ago the distance between locomotive terminals was shorter than is considered desirable now, and generally the divisions have been lengthened so that at the present time they range in length from 100 miles to 200 miles; divisions approximately 150 miles in length are quite common. Frequently there are locomotive terminals between the division extremes, but these are usually for local and suburban runs and are of lesser importance, although a few years ago they were the important terminals.

4 From the standpoint of operation, the engine house and its accessories at the divisional point should be located close to the freight

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yard, for freight locomotives, and to the passenger station, for passenger locomotives. This condition is more readily fulfilled for freight than for passenger service. For the latter it is sometimes necessary to place the engine house five to ten miles from the passenger station where the locomotive is detached from the train. This requires the introduction of separate crews for handling the locomotives between the engine house and the station and also necessitates exceptional methods of inspection and reporting and calling the crews and equipping the locomotives for the next trip. Such conditions exist at Buffalo on the New York Central & Hudson River R. R. On the other hand the station is not a terminal of the road the through trains may be if stopped near the engine house and the locomotive detached and attached there; such is the method on the Lake Shore & Michigan Southern Railway at Cleveland.

APPROACH TO THE TERMINAL

5 The route between the train terminal and the engine house should be as direct as possible and independent of all other movements. This is not always possible, however, and in passenger service more particularly, the route is largely made up of main line track. Especially is this true when the locomotive terminal is at some distance from the station.

LINE OF SEPARATION OF RESPONSIBILITY

6 So far as concerns the mechanical operation of the locomotives, the mechanical department must be responsible. There are two well recognized and quite different forms of railroad organization: the departmental, in which the mechanical department has supervision over the design, maintenance and mechanical operation of the locomotives; and the divisional, in which the mechanical department has supervision over the design, construction and general condition of the locomotives, and the transportation department has supervision over running, maintenance and mechanical operation. In either of these organizations the responsibility for the locomotives must change, so far as individual officials are concerned, at some place adjacent to the engine house. In some organizations this change is made at the turntable, or its equivalent, there are a very limited number of rectangular engine houses, notably at the St. Louis passenger terminal, where a transfer table is used and a turntable is not necessary. In these

organizations the official in charge of the engine house, who is a part of the mechanical department, has supervision over the movement of the locomotives between the table and the house and over the locomotives in the house; and the coaling plant, ashpit and other accessories are handled by the transportation department. In other organizations the engine house official has supervision over the entire engine house premises, including the coaling plant, ashpit and all other accessories.

7 It is not well established which is the better organization, and not only does the organization differ on different roads, but often the same road has changed several times from one arrangement to the other. It is probable, however, that the best arrangement is the one which provides the highest class official nearest to the place to be handled. The best results probably will be obtained from the present tendency to place a master mechanic at each of these important locomotive terminals and assign to him supervision over the entire plant. Such an arrangement will place the line of separation of responsibility for incoming locomotives on the approach to the engine house and outside of the coaling plant; and for outgoing locomotives at the track assigned for locomotives ready for service.

SEPARATION OF LOCOMOTIVES ON A DIVISION

8 On a division having only one important locomotive terminal it is not necessary to designate where the important repair work will be done, but on many divisions there are two or more engine houses thoroughly equipped for the complete maintenance of a certain number of locomotives, and on these divisions it is necessary to designate those which will be maintained at each house. Each engine house will do the periodic work and the running repair work on the locomotives assigned to it, and the inspection and safety repair work on any locomotive which is run into the engine house. The assignment of the locomotives to the different houses is made by the divisional mechanical officer, usually designated as master mechanic. There is more or less transference of locomotives from one division to another for temporary service, but there are serious objections to this, especially when the periodic work and reports are to be considered, and when the duration of the temporary service is more than a few days. On the large railroad systems it seems quite necessary that an individual locomotive record of periodic inspection and work be kept by the divisions and the transferring of locomotives from one division to

another for a week or two results in annoyances, errors and loss of records incident to transferring records when the locomotives are transferred.

LAYOUT OF A LOCOMOTIVE TERMINAL

9 It is not the intention of this paper to cover this item in such detail as would be necessary for the preparation of an ideal layout, but rather to deal in generalities which may be of greater interest in an international discussion. It will be in order to consider, first, the capacity of the various facilities which are to be supplied. It is desirable to rate the capacity on the maximum demand for a comparatively short interval of time, say one hour or two hours, for the coaling, ashplant, turntable, water and sand facilities; and for longer periods of time for other facilities. Some of these ratings may be consistently higher than the sustained rating of 24 hours. There should be considered also, how much of the terminal will become inoperative in case of accident to any one of the important units of the terminal, and the approximate length of time the resulting disorder may continue; and to provide the necessary assurance of continuous operation, by the installation of duplicate units. The water and coal plants and the turntable are the most important units and these will need special study.

10 Water columns are usually so well distributed at a division terminal that only a failure of the entire water system need cause much delay, so that the important consideration is convenience of location. The insurance may be taken care of in the general water system. An ample supply of water is also of prime importance.

11 For insurance of the coaling operation there may be selected one of several schemes, one of which is to place the cars of coal on one, and the locomotives on another of two or more adjacent tracks, transferring the coal from the cars to the tenders by hand or by locomotive crane. Another scheme is to coal the locomotive at the coal-stocking plant, if one is near by; or by other means, none of which seriously affect the general arrangement of the locomotive terminal.

12 On the contrary, insurance of turntable service will very decidedly affect the general layout of the terminal because the spare table must be capable of serving the whole or a considerable part of the engine house capacity, inasmuch as failure of one table may occur when a large number of the locomotives are in the house served by it.

The only way in which more than one turntable can serve one unit of engine house capacity, in a circular engine house, is by dividing the house unit into parts and having a turntable for each part. To accomplish this result it is considered very good practice to limit the size of a separate engine house to approximately a half-circle, and to provide any additional capacity in another half-circle, offset from the first at least enough to permit of a separate turntable for each. The separate turntables should have track connections to the inbound and outbound tracks, and usually have inter-connecting tracks.

13 For further insurance of uninterrupted turntable operation two motors for revolving each turntable are considered desirable, and even necessary, but both should not be operated from the same power plant. Sometimes two gasolene motors are used, and sometimes one electric motor is provided for general use and a gasolene motor for emergency use.

14 If the house is made up of parts of two circles, one end of each part will be placed near one end of the other, and the machine shop, storehouse, power house and offices will drop in very naturally between the two. The drop pits, overhead crane, and other special facilities necessary in a limited section of the engine house, will be placed convenient to the shop.

15 There remain to be located only the coaling plant, ashpit, sand house and water columns, which will be placed primarily for convenience in getting the inbound locomotives to them. There must be ample water facilities on the outgoing tracks and it is desirable to have a small ashpit and a sanding place on these tracks. If provisions are made to get the outgoing locomotives to the coaling plant on special occasions, then a coaling place is not necessary on the outgoing track. Of these facilities on the inbound tracks the ashpit will be nearest the turntable so that the locomotives may be moved the shortest distance when there is little or no fire on the grates. Sometimes it has been thought desirable so to arrange the facilities that coal, water and sand can all be taken at the same time; but if the hostler is to stay in the cab so as to be ready for moving the locomotive promptly, it is probable that the difficulty in arranging these facilities for the various lengths of locomotives will make it desirable to place them somewhat more than a locomotive length apart if the ground space permits. Sometimes a track arrangement is made that permits of advancing one or more locomotives around other locomotives, and when the ground space is available this is a good thing to do. The tracks on which the ash

cars are taken to and from the ashpit should be independent of the inbound and outbound locomotive tracks.

THE ENGINE HOUSE

16 The cross-section and other details of construction of the engine house have such important relations to the prompt handling of locomotives at terminals, especially in the colder climates, that it is well worth while to refer to them.

17 The two items which have been given most consideration during the last few years, for houses located in the colder climates, are the heating and the ventilating; they are so closely related that they should be considered together. For low cost of heating, the area of the cross-section should be as small as the locomotives will permit and until recent years it was the practice to follow this principle in the design. Unfortunately, good ventilation, which is equally important, has not been obtained with the small cross-area and as a result the condition of fog and smoke, and principally fog, in these low-roofed houses in cold weather is such, at times, as scarcely to be understood until seen.

18 A decided improvement in ventilation has resulted from raising part of the roof somewhat higher than the necessary headroom would require, placing the ventilators at the top of this higher portion. The design of these ventilators is undergoing a process of development and at present practically each road has its own preferred design. An advantage of this high roof section is that additional area for windows is given in the enclosing wall, and this additional lighting is important for the wider houses now necessary.

19 In the effort to reduce to a minimum the fog in the house in cold weather, special efforts are also made to prevent the escape of steam from the locomotives. To this end a pipe line of large diameter is placed around the house, usually above the locomotives, with terminals conveniently arranged for making quickly a pipe connection to a valve in the top of the boiler. To reduce the steam pressure in a boiler the steam is blown through this pipe into the atmosphere, or to water-heating tanks or hot wells.

20 Pipe lines, including cold-water, hot-water and steam lines, are similarly arranged for washing out boilers, and provision made for mixing the cold water with hot water or steam to get the desired temperature for washing. The same pipe lines, or others, conduct the water from the boiler to storage tanks and reheaters. The smoke-

jacks have elongated bases which cover the safety valves as well as the stack.

21 The heating is done by one of two methods: by direct radiation from steam pipes placed on the side walls of the pits; or by hot-air blast. Probably the latter is preferable. The place of delivery of the heat is as near the locomotive as possible. The capacity for the steam heating is usually all that can be obtained from two to six 2-in. pipes on each side wall in the pit and some on the outer wall of the house; for the hot-air system the capacity is the volume of the house every ten to fifteen minutes, at a temperature of about 60 deg. fahr. A very important point about heating engine houses is to keep the doors and windows closed and to cover the usual openings at the bottom of the doors. It is desirable also that the roof timbers be so placed as not to interfere with the flow of air upward along the roof to the ventilator outlets.

22 It is the general practice to provide several tracks in the house, with a drop pit into which to drop driving and truck wheels, and to provide in the same section of the house an overhead crane for loading to and unloading from cars these wheels, and for handling air pumps, cabs, boiler fronts and other heavy parts to and from the locomotives. Light portable cranes are provided for lifting steam chest covers, rods, and other heavy parts which do not require high lifts.

23 There are many smaller details about engine house design and equipment which contribute to the rapid and efficient handling of locomotives, but it will be best not to burden the paper with them.

THE COALING PLANT

24 The uninterrupted operation of this plant is of prime importance, and with this in mind, that design should be chosen which is least liable to be deranged and which can be repaired most quickly. With sufficient ground space available, these considerations will make the choice a trestle, so that cars of coal can be pushed or hauled up an incline and the coal dumped direct from the cars into the bins from which it slides by gravity into the locomotive tender. This kind of plant reduces to a minimum the breakage of fragile coal, sometimes an important feature. If the incline approach is too steep for steam locomotive operation, the motor and winch should be in duplicate and the motors not dependent upon the same source of power, unless there is little chance of total disability of the source.

is little chance of total disability of the source.

25 When the ground space is limited the mechanical hoisting plant, of the bucket or a similar type, is a necessity, and it has been selected sometimes when the available space would permit of a trestle. There are various forms of the mechanical plant, but it will be unnecessary to consider them in detail. Usually they are placed crosswise of the tracks. Sometimes the same apparatus used to elevate the coal is used to convey ashes from the pits and to deliver them into storage bins or into cars. This combination has the advantage of concentration of facilities when such concentration is necessary, but there are objections to it otherwise. To give the necessary capacity at the coal pockets and ashpits a greater number of tracks are necessary and the risk of personal injury from coal falling from the tender and striking the men who must be about the ashpit is increased. This concentration will shorten and widen the approach to the engine house.

THE ASHPIT

26 It is desirable to have a pit capacity immediately beneath the locomotives for several hours' busy dumping of pans and grates, whether the ashes are handled by hand or by machinery from the pit to cars. If handled by hand this is to provide for economical time distribution of labor; if handled by machinery, to provide for continuous dumping when the machinery is out of order. The economical transferring of ashes from pit to car by hand requires a lower pit for the ash cars, adjacent to the ashpit, and sometimes conditions do not permit of such an arrangement or of the necessary track approach. If the ash pan and fire cleaners can be used for transferring the ashes from pit to car, at intervals when there are no pans or grates to be cleaned, the manual labor can be most economically distributed. The mechanical plants usually operate crosswise of the pit, limiting the length of pit undesirably, and making necessary several pits side by side or a further mechanical installation for transferring the ashes lengthwise of the pits to the cross conveyor. With each addition to the mechanical devices, complications are multiplied. Water hydrants for hand hose are located conveniently about the ash pits, and shelters are provided near by for the men to occupy when there is a lull in the work.

THE SANDING PLANT

27 The sand-drying plant should be located convenient to the inbound tracks, but not necessarily adjacent to them. Convenience

in delivering wet sand to the drying plant is important. As air pressure is used to elevate the dry sand to the storage bin from which it falls by gravity to the locomotive sand box, air pressure can also be used for transferring the dry sand for some distance horizontally, so that the place of delivery for the wet sand may be conveniently located for such delivery. Sometimes the sand is dried on steam-heated tables, but since the temperature cannot be raised high enough for satisfactory drying, the preferred dryer is the stove. The dry sand bin, from which the sand is delivered to the locomotive, is usually located between the coaling plant and the ashpit.

WATER SUPPLY

28 Water columns should be conveniently located on both inbound and outbound tracks.

THE ORGANIZATION

29 *The Master Mechanic.* The usual divisional organization places one man, the master mechanic, in charge of the locomotives on the division, both when the locomotives are away from the engine house and when at the engine house. One of the division terminals is under his supervision and his headquarters are generally at that terminal because it is the important point of his jurisdiction. He may have assistants with duties both at terminals and between them, and he always has assistants, called assistant master mechanics, who confine their efforts to the terminal, and others who confine their efforts to the road work. If at the divisional terminals the freight locomotives and the passenger locomotives are separated, as is often the case, one assistant may have supervision over freight locomotives and terminals, another over passenger locomotives and terminals, and a third over the intermediate division engine houses, in which both passenger and freight locomotives may be cared for.

30 *Traveling Foremen.* The assistants in the operation on the road are usually designated as traveling engineers or road foremen of engines, and traveling firemen. Some are assigned to passenger service and others to freight service, and they report to the master mechanic, or if there are assistant master mechanics, then to the proper assistant master mechanic. Their duties are, nominally, to instruct the engine drivers and the firemen; to report the conditions of the locomotives as delivered from the engine house; to foresee, when possible,

and to report work on the locomotives which may require special preparation or special attention for the preparation of material, etc. Too often, and it may be said usually, they are kept busy ascertaining and reporting what has already happened and explaining it, whereas their efforts should be directed to preventing the repetition of undesirable occurrences. It is conceded, however, that a general knowledge of what has happened and the causes is essential for the intelligent direction of means for preventing recurrence.

31 All of these officials, from master mechanic to traveling firemen, are subject to call at any hour.

32 *Engine House Foremen.* The organization at the locomotive terminal will begin with the general foreman, who will have general supervision of the terminal 24 hours a day and seven days in the week. He will have personal supervision in the daytime; the assistant general foreman will report to him and have supervision at night. These two may arrange between themselves, subject to the approval of the master mechanic or the assistant master mechanic, for regular rest days. The division of the 24 hours between these two men means somewhat more than 12 hours a day service for each, that there may be time for the necessary consultation between them. Because of this and the fact that the change in supervision is made in the morning and evening, the busiest hours at most engine houses, and at about the same time the other employees change shifts, there is being considered, and in fact put into operation at a few places, an arrangement for 8-hour shifts, so assigning the terminal men that the entire shift will not change at any one time. In such an arrangement the general foreman would be present during a part or the whole of every shift and one of his three assistants would be assigned to each shift. Twenty-four-hour operation is necessary at engine houses and two complete breaks in each 24 hours are not conducive to best results, nor can a man deliver his best efforts for 12 hours a day continuously. Hence the tendency to shorten the hours of daily service and to minimize the effect of each change of shift.

33 In addition to the assistant general foreman, the store-keeper and chief clerk will also report to the general foreman. To the assistant general foreman in charge of each shift, the yard foreman, the house foreman, the shop foreman, the foreman of laborers, the despatcher and the necessary clerks, will report.

34 *The Yard Foreman.* He should have complete charge of the locomotives at the terminal and outside of the house. He should take from the house foreman instructions as to the particular stall in which

from the house foreman instructions as to the particular stall in which

each locomotive is to be placed and report as soon as it is placed; and should take from the despatcher instructions about delivering the locomotives to the transportation department. This arrangement will place under the supervision of the yard foreman, the coaling, sanding, watering and ashpit plants, and the turntables; the care of the locomotives which are standing outside of the house; and also the special crews that run the locomotives between the engine house and the train terminal, when such crews are necessary.

35 *The House Foreman.* He should have supervision over the workmen in the house, and over the inspectors on the incoming track, if there are such inspectors. The various foremen reporting to him are those in charge of repairs to tenders, boilers, machinery and air brakes, and others similar, depending on how far the work is specialized. In working out the 8-hour shift arrangement, it has been suggested that there be assistant house foremen, each with supervision over certain stalls assigned to him; the special work, however, such as air brake and similar work, to be done by special gangs for all the stalls. The shop foreman will also transfer machinists, boiler makers, etc., from one assistant foreman to another, as conditions may demand. This arrangement of dividing the house into sections, each in charge of an assistant foreman, is being used with satisfactory results. It makes of the assistant foreman a high-class inspector because it places him in such close touch with the conditions that he can say just what work should be done, and know how thoroughly it is done. This is a most important consideration because the engine men and inspectors may report a lot of work to be done, partly to clear themselves, as well as to inform the foreman thoroughly. The man who does the inspecting and repairing on a locomotive or on a number of locomotives day after day, is well informed on what must be done and how it should be done; which leads to the suggestion of the further step that the maintenanck of certain locomotives be assigned to certain gangs. This ought not to be impossible in passenger locomotive terminals.

36 *The Shop Foreman.* The importance of the shop foreman depends largely upon the importance of the shop. Sometimes his duties are assumed by the engine house foreman. The tendency seems to be in the direction of providing larger shop facilities, and as these are increased the importance of the shop foreman will increase.

37 *The Work Report Clerk.* The clerical force perform the usual duties of such employees. There is one clerical position, however, which is growing in importance and the qualifications for the filling of which are becoming more and more exacting; this is the position of

work report clerk. He should understand clerical work and know enough about locomotive parts and repairs to make out a satisfactory report of work to be done. He first comes into contact with the arriving engineman, who reports on conditions which can be observed only when the locomotive is in action. Enginemen do not like to write, hence their written reports are short and unsatisfactory. The tendency at present therefore is for the clerk to write these reports for the signature of the engineman and the clerk must understand what work is necessary and report it properly. As the clerk is almost always accessible, the information is thus available in case further explanations are required. This clerk also makes a record of the incidents of the trip as reported by the engineman, so that in case of inquiry, the desired information is already on file.

38 The engineman's report of work to be done and the report of the inspector should reach the work report clerk at the same time, that there may be no delay in distributing the work to the respective gangs.

39 *Bulletin for Completed Work.* Quite as important as having the work to be done promptly reported to those who are to do it, is the reporting back promptly when the work is completed, and to have this information easily available for those who need to have it. For this purpose various arrangements are provided, the details being worked out to suit the peculiar layout of each house. The essential features are provided by a blackboard located conveniently for those who make the records and for those who must read them. This board is ruled into vertical columns, one for the number of the locomotive, one for the number of the stall in which the locomotive is located, and other columns, depending upon how the work in the house is distributed among the repair men. For instance, there may be a column headed "air brake," another "boiler," another "machinery." As each class of work is completed each foreman marks on the board in the proper column and opposite the particular locomotive number his "O. K.," indicating that his work on the locomotive has been completed. When all the spaces opposite a locomotive number are marked "O. K.," it is evident that the locomotive is ready for service. The record is erased as soon as the locomotive is taken out of the house. The convenience and despatch with which these records can be made are important factors.

40 *Outfitting the Locomotive.* Contrary to the previous practice of requiring the locomotive crew to do some cleaning, fill oil cups, and in general look after the outfitting of the locomotive, the present ten-

dency, and it is pretty well established, is for the engine house force to outfit each locomotive completely for service on the road. There remains for the crew, of course, the responsibility to know that the necessary repairs and outfitting have been done, even though the locomotive is delivered to them at the station.

41 *The Despatcher.* It remains for the despatcher to know what locomotives and crews are arriving, and to care for the proper despatching of locomotives and crews

POOLING.

42 Some years ago it was the general practice to assign a locomotive to a crew and both crew and locomotive to particular runs, and when the locomotive was taken to the shop for repairs the crew worked in the shop until the repairs were completed, usually devoting much, or all of its shop time to its locomotive. At that period there were few extra passenger runs and the freight runs were very largely scheduled runs, under which conditions it was easy to assign locomotives to crews and crews to runs, keeping each crew on its particular locomotive and run. As the maximum freight service increased and the fluctuation between maximum and minimum freight service widened, it became necessary to move a large proportion of the freight trains as extras, which made it quite impossible to assign crews and locomotives to runs not scheduled. It was also necessary to increase or to decrease the number of locomotives in proportion to business demands, which could be done only by withdrawing locomotives from service, during which time there would be only the interest and depreciation charges on them.

43 As a result a plan was developed to increase the service of the locomotives by placing any crew on any locomotive for service, instead of holding it until its assigned crew could obtain the necessary rest. While this prevented the assignment of locomotives to crews it made possible a larger individual locomotive mileage per month or per year. The first experience with this arrangement in freight service seemed so satisfactory that it promised well for passenger service to which it was extended, so that a locomotive used one day on one train would be used the next day on a different train, permitting the operation of a certain number of trains per day with greater or less number of locomotives than trains. The idea, of course, was to operate a number of trains with a less number of locomotives.

44 The criticism most generally made upon this system is that the personal interest which the man had originally in his own locomotive is lost. This has been valued very highly by some officials, more particularly those of the motive power department, and less

highly by others, usually of the transportation department and more particularly those who are not so well versed with the trials and tribulations of the motive power department. Under the pooling system the effort of the average crew is to get through with the particular locomotive as quickly and as easily as possible and to let the next crew get along as best it can.

45 Such conditions necessitate careful watching of the reports from the enginemen so that everything that the engine house inspector cannot well find is included, and also careful inspection and repairing at the engine houses. It may make necessary also, an additional expense per locomotive for wear and tear, as some argue, and at the engine houses, as others argue; but whatever the cause or amount, this additional expense is the cost of getting the additional mileage per locomotive per month or per year, and it is a question of whether the cost is more than offset by the gain. The argument that it is as well to get the mileage-life of a locomotive in fifteen years as in ten neglects the fact that possibly 50 per cent more locomotives will be required if it is gotten in fifteen years than if in ten years, with a resulting interest charge.

46 Possibly, also, those who hearken back to the times of assigned locomotives and crews and picture to themselves the enginemen setting box wedges and rod brasses, adjusting the piston rod packing and doing a long list of other work overlook the difference in the size of the parts of present and past locomotives, and that a crew even if it knew a certain work was required and was willing would be unable to do it, at least alone. Extensive experiments have been made to determine the relative costs of the assigning and the pooling systems and in some of these experiments at least, no material difference in cost has been found. However, there may be, and probably is, some loss in reliability of service in pooling.

47 The fundamental idea of pooling is to obtain from each locomotive the maximum mileage per month or per year, in other words to keep the locomotive going, and various schemes have been devised to accomplish this and to obtain at the same time any advantages there may be in the personal interest of a crew in its own locomotive. One of these is to assign one locomotive to two or, at times, three crews, each crew making a round trip from terminal to terminal. A variation is to change the crews about midway in the trip; this has some decided advantages, the principal one being that a fresh crew is obtained at the beginning of each quarter of a round trip, or each half of a single trip, and while the rest at each terminal is not of long

duration, yet it means much to the crew, especially in hot weather; also, inasmuch as the crew is not at home at the divisional terminal, the men are anxious to start back so that they may reach home. To work out satisfactorily this system of changing crews at the middle of a division, it is necessary that the divisions be so arranged, or of such length, that there shall not be too much constructive mileage for the crew; that is, that the mileage for which the crew is paid shall not be materially less than the actual mileage made by it.

48 Since it is quite certain that a locomotive in proper condition for service can be used a greater number of miles or hours per week or per month than one crew is able to stand, it would seem to be good policy to get full returns in some way and not limit the output in miles or in hours service to the capacity of the crew; on the other hand, the men must be given proper consideration and be permitted to make fair wages. The pooling of locomotives and of crews in the different kinds of service makes it possible to use each locomotive the maximum number of miles in a certain period of time, which maximum will be about the same as for any other locomotives in the same service, granting, of course, that nothing serious goes wrong with it; it also makes possible maximum and equal earnings by men of physical equality.

49 The assigning of one locomotive to one crew limits the output obtained from the locomotive during a month or a year to the capacity of the crew; assigning one locomotive in road service to two or more regular crews need not limit the output of the locomotive but may place the earnings of the crew below its ability and below average earnings for similar work. In yard service it is possible and is the general practice to assign one locomotive to two crews. If in road service one locomotive is assigned to two or more crews, the run should be arranged to permit each crew fair earnings. Another variation of the pooling system is to assign two locomotives to three crews, to which resort may be made when two crews on one locomotive cannot make the average earnings.

50 It will be noted that the original idea of pooling was to obtain maximum mileage from the locomotives, which resulted, apparentlly, in taking from the crews and placing upon the engine house a large part of the responsibility of the condition of the locomotives; then appeared variations which had in view this original idea, coupled with the effort to place upon the crews at least a part of the responsibility for the condition of the locomotives taken from them or voluntarily given up by them under the straight pooling system; each arrangement having in mind a fair earnings return to the crews.

ENGINE HOUSE PRACTICE

OR THE HANDLING OF LOCOMOTIVES AT TERMINALS TO SECURE CONTINUOUS OPERATION

By F. H. Clark,[1] Chicago

Member of the Society

The topic assigned me is so comprehensive as to embrace nearly all features of engine house practice. In order to get the matter clearly before the meeting, therefore, it may be desirable to describe briefly such features of design and equipment as are considered good practice in the United States.

ARRANGEMENT OF LOCOMOTIVE TERMINALS

2 The engine house and its appurtenances should be located, when possible, at a point near the yard or station where the engines are released or required, though the plan must usually be adjusted to meet existing conditions of topography or space. In Fig. 1 is shown a plan which may serve as a basis of the paper. It has no unusual features, but it may be considered a fair example of engine house practice. Some space might be saved by the use of a different design of cinder pit, and considerable space by a different coaling station. Other modifications would naturally suggest themselves in considering the application of the plan to any specific case.

3 The approach to the engine house provides two tracks for incoming engines, one on either side of the coaling station, and one track for outgoing engines; though connections are provided by which the movement may be varied if necessary.

4 The coaling station indicated on the plan is of a design frequently employed in locations where space permits. Fig. 2 shows its

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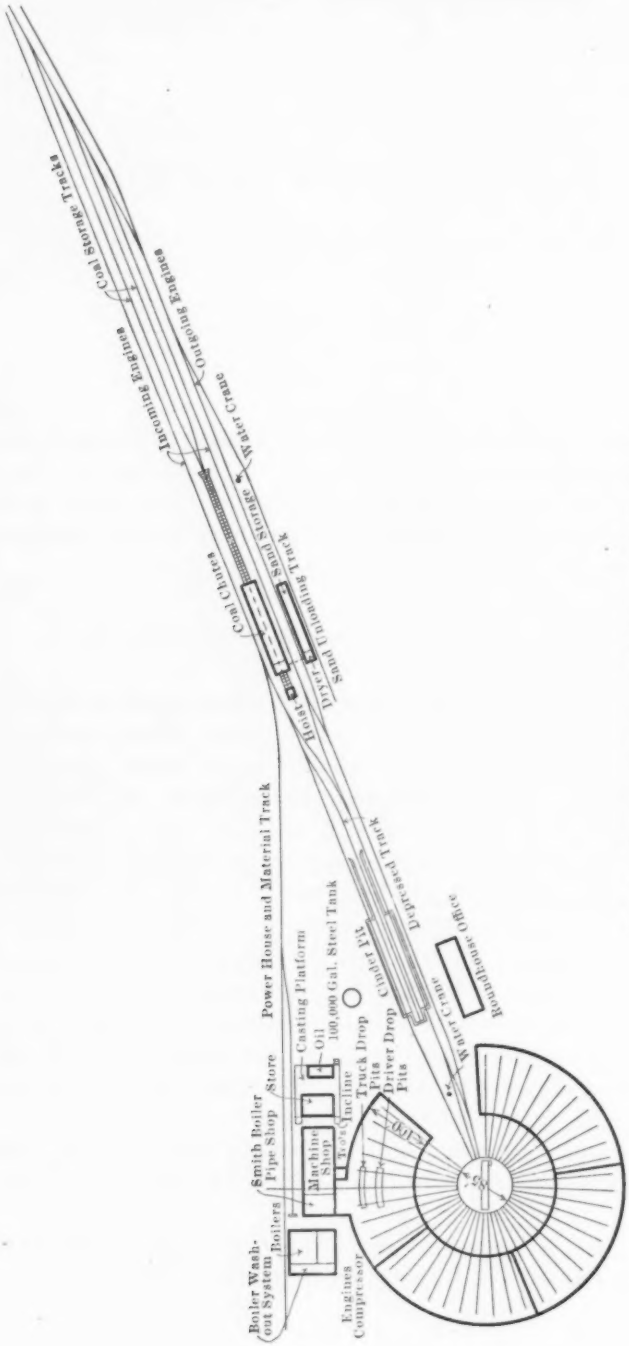

FIG. 1 ARRANGEMENT OF LOCOMOTIVE TERMINAL

general construction, but with the tracks at right angles with the center line of the structure, instead of parallel to it, as in Fig. 1. The coaling station illustrated is of 700 tons capacity. The coal is elevated in cars by means of a hoist which pulls the loaded cars up a 20 per cent incline at a rate of about forty feet per minute. The coal is shoveled or dumped out of the car directly into bins or pockets, if breaking is unnecessary; or on a grating of breaker bars spaced four to six inches apart, through which the coal drops when broken. The

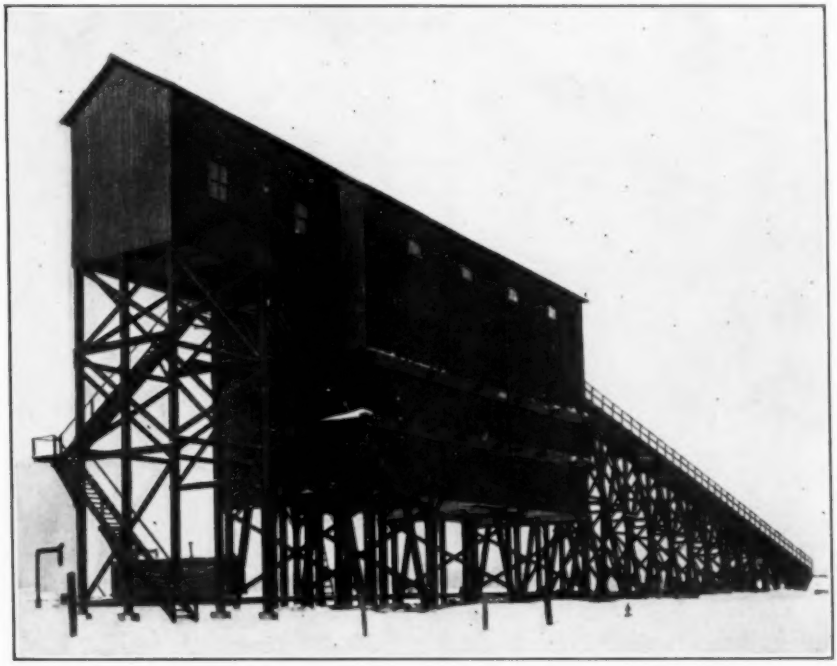

FIG. 2 COALING STATION WITH TRESTLE

station delivers coal to six tracks, five underneath and one at the end. The hoist may be operated by steam or gasolene engines, or by electric motors, motors being usually considered preferable where electric current is available.

5 Another type of coaling station is shown in Fig. 3. This station has an overhead storage capacity of 1200 tons, and the construction is entirely of steel and concrete. The coal is hoisted in a pair of Holmen counterbalanced buckets, and distributed in the bin by means

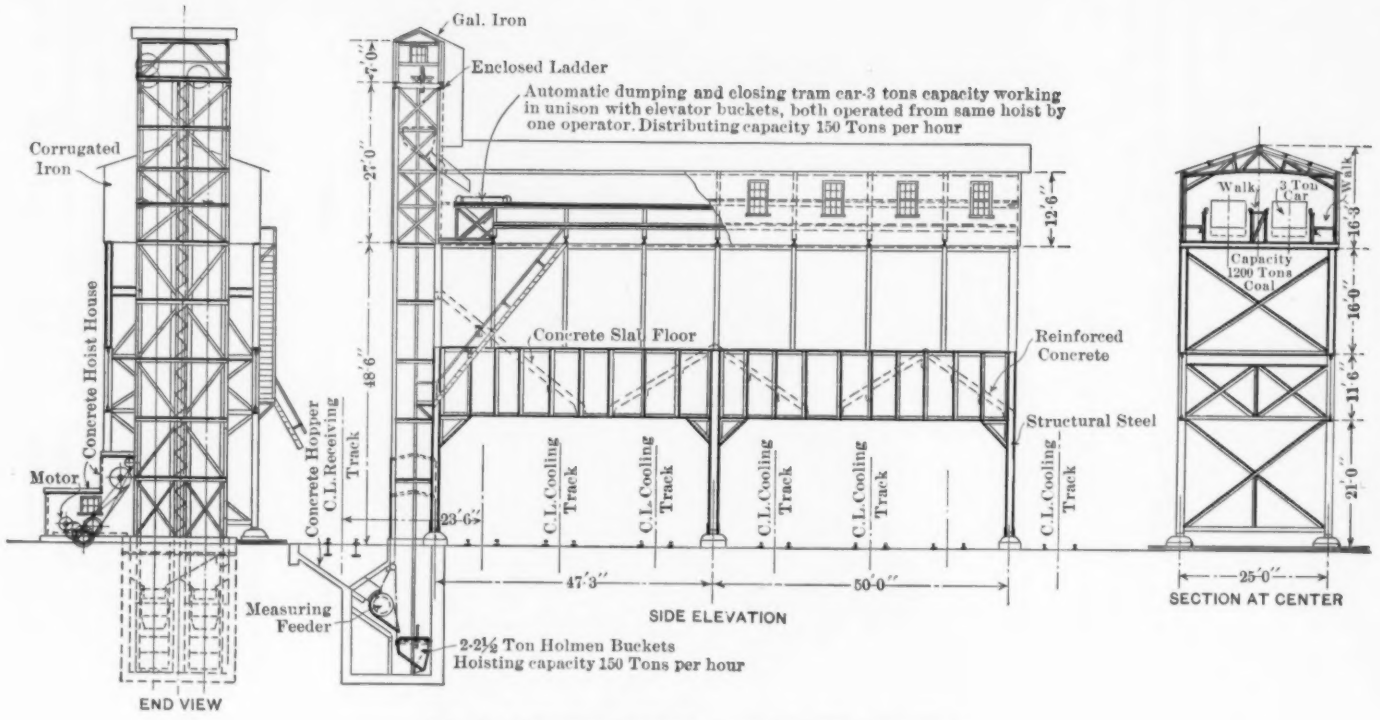

FIG. 3 COALING STATION WITH BUCKET ELEVATOR

of a special automatic tram car. The coal is received at one side of the bin and is delivered to five coaling tracks, four underneath the pocket and one adjacent. To facilitate the handling of cars of coal during the winter, three additional receiving hoppers are provided, so that coal frozen in the bottom of the cars may be removed without interrupting the main hoist. The coal is then transferred from the three hoppers to the main hoist for elevation to the overhead pocket. This plant is operated by electricity.

FIG. 4 100,000 GAL. STEEL WATER TANKS

6 Various other types of coaling plants are in successful use, the coal being elevated by belt conveyors or small bucket conveyors, or handled by cranes of various types, with clam shell or similar buckets. The cost of operation ranges from two to ten cents per ton, depending upon various factors.

7 The sand-drying apparatus shown in Fig. 1 is placed opposite the coaling station, though frequently a part of the coaling plant is used for that purpose. One of the most common methods of drying

sand is by coal stoves, which differ considerably in design. The moist sand is delivered from a hopper to a casing surrounding the stove, from which it escapes as it becomes dry. Some of the more modern sand-drying houses use exhaust or high-pressure steam from the power house. After drying, the sand is usually hoisted, by means of compressed air or by some form of conveyor, to a storage bin, from which it is drawn by locomotives when needed. Rotary sand-dryers, in which sand is fed into an inclined tube through which a current of hot air passes, are not commonly used, but could no doubt be used to advantage if a considerable amount of sand were required.

8 The water supply for locomotive use is usually stored in overhead tanks of various capacities. Fig. 4 shows two steel tanks of 100,000-gal. capacity recently erected. The body of the tanks is unpro-

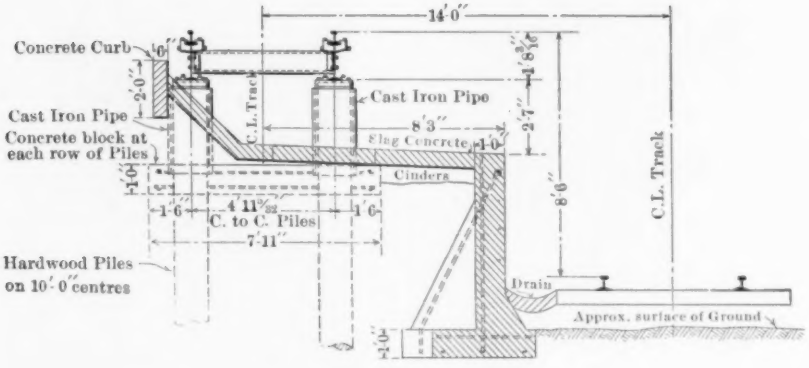

FIG. 5 HALF SECTION OF ELEVATION CINDER PIT

tected from the cold, but the connection between tank and water mains is usually enclosed, as shown, in places where freezing is likely to occur. Standpipes, or water cranes, are so placed that water may be taken without backward movement. Ten-inch cranes are frequently found in modern installations. These will deliver 2000 to 3000 gal. of water per min. under usual conditions.

9 Cinders and clinkers from incoming engines are handled in various ways. An arrangement in common use which has proved very satisfactory is shown in Fig. 5. The contents of the ash pan are dumped on a platform about four feet below the top of the rail, with a slight incline toward a depressed pit into which cars are run for load-

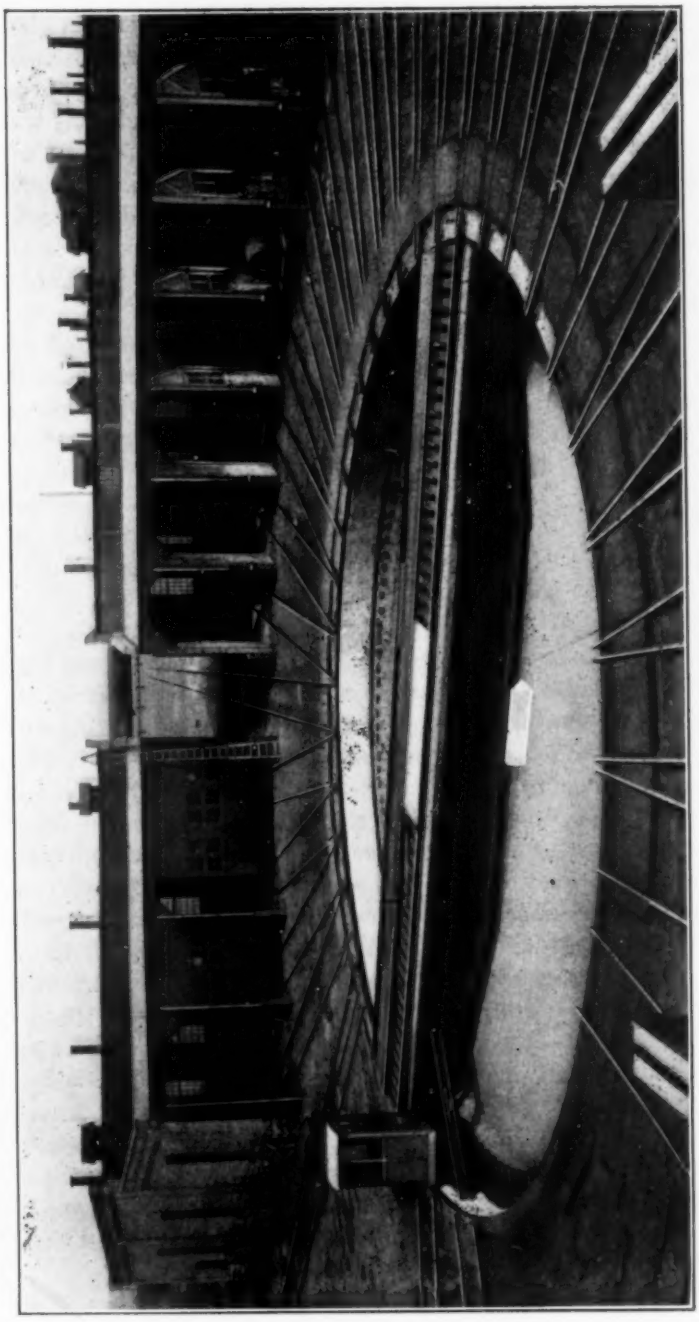

FIG. 6 MOTOR-DRIVEN TURNTABLE

ing. In Fig. 5 the rails are shown supported on wooden piles, the upper ends of which are surrounded by cast-iron pipes, with insulating material packed between the pipe and the pile. The use of concrete piers is considered preferable where foundation conditions will permit. The cinders and clinkers removed from the ash pan are wet down and shoveled into an open coal car standing in the depressed pit. With engine tracks on each side of the pit, several engines may be accommodated at a time, and the plan affords considerable storage capacity, so that, with a pit of moderate length, a day force of shovelers is sufficient to take care of the accumulation.

10 In some modern plants the slope from the outer rail delivers the refuse from the ash pan into a concrete pit about eight feet in width and depth and filled with water. In this case the material is removed by means of a traveling gantry crane with clam shell or similar buckets, and delivered to cars standing on the side of the pit opposite the engine. In other cases pits are provided between the rails, in which buckets are placed, and the buckets are lifted out and the contents deposited in open cars by a gantry or ordinary overhead electric-driven crane with elevated runway.

11 The engine houses of the United States, usually being circular in form, require turntables for the delivery of engines to and from the house. A common length of table for new installations is 80 ft., though a great many shorter tables are still in service, and working satisfactorily where the length of engines is not too great. Turntables are frequently moved by hand, though a more economical method, where a considerable number of engines are turned, is by tractors driven by gasolene engines or electric motors. Fig. 6 shows the application of such a tractor to a turntable. The tractor has a heavy steel frame of triangular shape attached to the turntable by means of hinges at two points, the weight being balanced on the single tractor wheel traveling on the circular rail in the pit. On this frame are mounted the motor, gearing, bearings, shaft and brake, comprising the driving mechanism. Above the machinery, and entirely covering it, is mounted the operator's cab, in which the operating mechanism is located. Electric motors are generally considered preferable where current can be provided uninterruptedly, and on such installations a collector device is applied to the turntable center. This maintains a connection with the feeder line, which is brought underground to the center of the pit, though, in case the pit is subject to flooding, an overhead collector may be used.

FOLDER No. 1

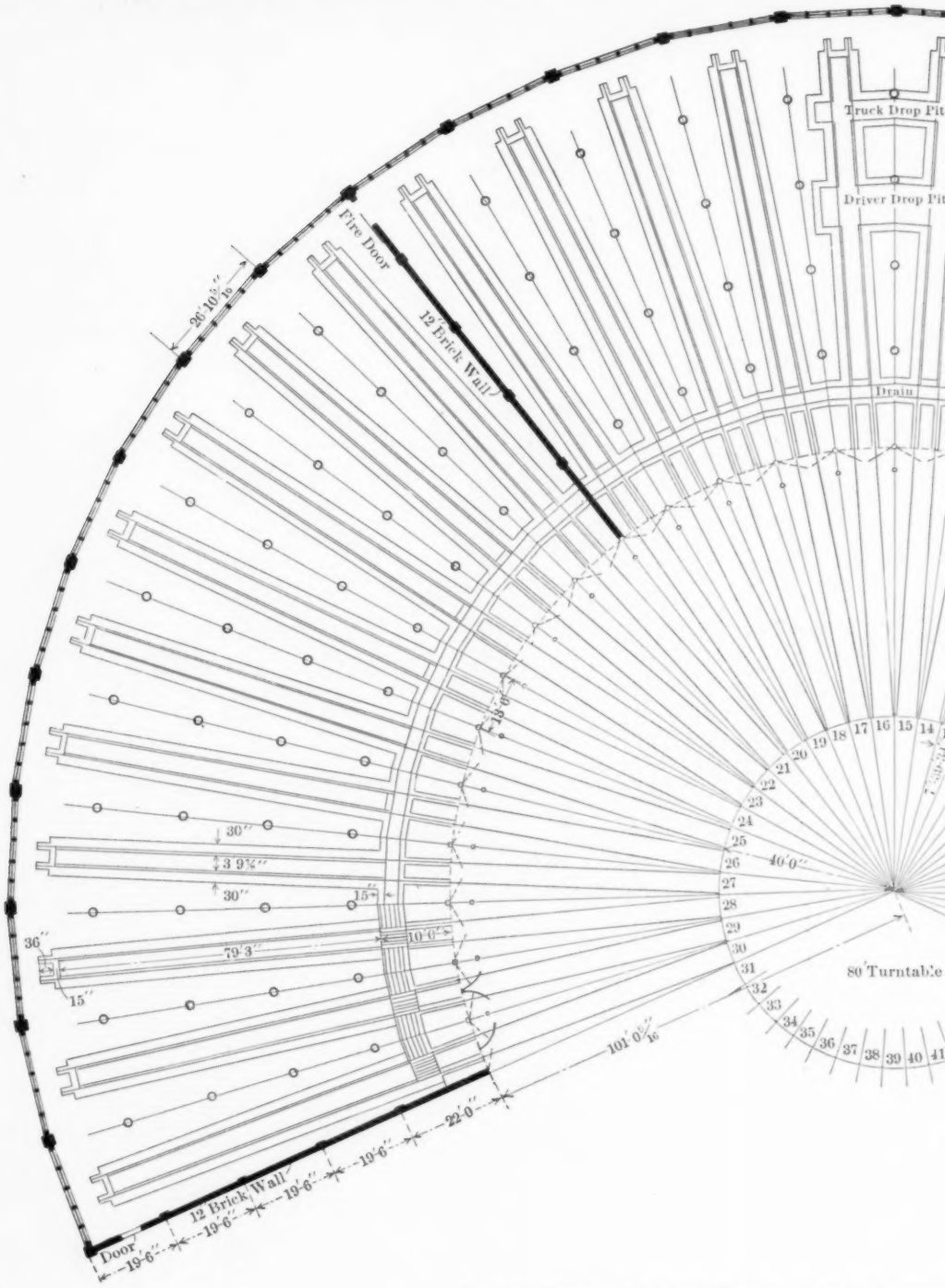

FIG. 7 PLAN OF ENGINE HOUSE WITH 30 STALLS

30 STALLS AND PROVISION TO CONTAIN 47 STALLS

THE ENGINE HOUSE

12 Fig. 7 shows the plan of an engine house with thirty 100-ft. stalls and an 80-ft. turntable, on a circle having a maximum provision for forty-seven stalls, including inlet and outlet tracks. This plan shows fire walls separating the house into three rooms of ten stalls each. The two center stalls are provided with drop pits, by means of which driving and truck wheels may be removed and replaced without jacking up the engine. The engines in this house are intended to be headed in and backed out.

13 Reinforced-concrete framing is frequently employed, though the roofs are generally of wood and covered with tar and gravel. The use of exposed iron or steel in roof construction is generally avoided because of the rapid corrosion. The pits are connected at the inner ends by a drain from which the water escapes through an outlet sewer emptying into a large catch basin, or sump, where the sediment is deposited.

14 The pits in this case are recessed for steam-pipes, though the use of fan blast for heating engine houses is becoming more and more general, and it is usually found that better results are obtained by the use of vitrified tile ducts laid underground and discharged into the sides of the pits, than by the use of galvanized pipes above ground, which generally need frequent renewal. An important advantage of the fan blast is that it assists in ventilating the house, changing the air in from eight to thirty minutes, as usually installed and operated.

15 There are a great variety of smoke jacks in use. The type which seems to be coming into favor, is conical in shape and is frequently made of wood, lined with sheet asbestos or similar material. Smoke jacks are generally provided with dampers in houses where fan heat is used, and a space is sometimes left open around the jack for assisting in ventilation.

16 The satisfactory lighting of engine houses is a difficult problem. Oil, gas and electricity are commonly used. Incandescent lamps do very well if kept clean, and have the advantage of portability, separate circuits being frequently provided for extension cords, so that light may be carried to any point where it is needed.

17 Floors of vitrified or paving brick, crowned sufficiently to drain to the pits, have been found very satisfactory.

18 Drop pits for the removal of driving and truck wheels are very convenient. They are frequently made to span three tracks and of width sufficient to take the largest wheel handled. The jacks used

in these pits are generally mounted on carriages, running on rails laid in the pits, and they are usually operated by air or water, though screw jacks are sometimes used. Hydraulic jacks are usually considered preferable to air jacks because of their more positive action. Cranes are generally provided over drop pits.

19 The shop facilities necessary at the engine house depend upon the distance from large repair shops. Generally speaking, the tool equipment should be sufficient to take care of running repairs, though if the house is located near a repair shop some of the machinery that would otherwise be necessary may be dispensed with. There should also be a tool room, conveniently located with respect to the machine shop and engine house, in which small tools of all kinds can be conveniently kept and drawn as required. The storehouse should be similarly located and should carry a sufficient amount of material to handle the repairs frequently necessary.

20 There is nothing of particular interest to be said about the power plant of the average engine house. Boilers, engines and other equipment may be of any type desired. It seems to be the custom to figure on about ten boiler horsepower per stall and, on account of the common use of air tools, a compressor capacity of about 20 cu. ft. of free air per minute per stall is usually provided.

21 Oil houses are generally of fireproof construction, with the oil stored in a separate room from the place of distribution, from which it is drawn or pumped from tanks as required. The oil is usually stored in tanks in the basement, the size and number of the tanks depending upon the amount and variety of oils used. Self-measuring pumps are extensively used in modern installations.

22 Of recent years there has been considerable demand for better and quicker methods of boiler washing, and as a result several systems have been introduced. One of the earlier arrangements consists of an open cistern of perhaps 100,000-gal. capacity, located near the engine house. In this the steam blown off from locomotives is used for heating water to wash out the boiler, and in some cases also for heating fresh water with which to refill it. Recent installations are the National, which is of the closed-heater type, in which the steam and water blown off are used for washing out and for heating fresh water; and the Raymer system, which is of the enclosed-heater type and performs similar functions. Blowing-off, washing and filling connections are generally provided between alternate stalls in the engine house.

23 Locker rooms are generally provided for engine men, and fitted

with a sufficient number of expanded metal lockers to accommodate their clothing and small tools. These are located in a building near the engine house office. Lockers are also provided for shop men, and are frequently located inside the engine house on the walls of the building. The lockers are generally made of sheet steel with openings for ventilation. At points where boarding and lodging houses are not conveniently accessible, bunkhouses are frequently provided for the accommodation of the enginemen. These are usually provided with toilet rooms, shower baths, etc.

THE ENGINE HOUSE ORGANIZATION

24 The details of handling engines vary greatly on different roads. It seems to be generally customary, however, to have the engineer relieved at the coaling station by a hostler, though at some plants inspection pits are encountered before the engine reaches the coaling station, and the engineer is relieved at those points. In some cases also the cinder pits are reached before the coaling station, though it is generally considered better practice to have the cinder pits next to the engine house, so that if the fire is dumped the engine will have but a short distance to travel and encounter but little delay before reaching the house. The hostler, however, takes coal, water and sand, and moves the engine to the turntable and thence across to the house.

25 The engineer makes out a statement on arrival, commonly called a "work report," on which he indicates the condition of the engine and any work which he may know to be necessary. The engine usually receives an independent inspection, however, and notes are made of any work required which has escaped the attention of the engineer. The foreman, or his assistant, distributes the work and is responsible for its performance.

26 Especially at large terminals, engines are frequently stored outside and do not enter the house except for boiler washing or heavy work of some kind. Switch engines, especially those that work night and day, are usually so handled.

27 The organization varies with the requirements, but the engine house and its plant are generally in charge of a foreman who has general supervision over the inside and outside operation. He reports to the master mechanic or general foreman, and attends to locomotive repairs and service including the assignment of enginemen to their runs. He usually has an assistant who attends to the dis-

tribution of work, including the supervision over such foremen of the various classes of work as may be required. Efforts are usually made to keep the night work as low as is consistent with the prompt handling of engines coming in for service or repairs.

28 The cost of service varies greatly at different points. Most roads do the greater part of their work at the more centrally located engine houses and comparatively little at outside points. This naturally causes a considerable difference in the cost of service, but in addition to this, various local conditions, such as the quality of boiler water available, the condition of track, the general condition of the power, and the available help and wage scales, have a considerable effect upon the cost of service. On one road with which the writer is familiar, the cost of service per locomotive varies from 50 cents, or even less, at outside points, to about $3 at one or two important central points where a considerable amount of heavy work is done. The average cost by months for all engines housed during the eight months from July 1909, to February 1910, ranged from $1.50 to $1.73. These figures include service only. The average cost per engine for the eight months is shown in the table.

AVERAGE ITEMIZED COST OF ENGINE HOUSE SERVICE PER MONTH PER ENGINE

Passenger Engines

Hostling	$0.12
Calling	0.08
Wiping	0.41
Cleaning	0.26
Headlight cleaning	0.07
Boiler washing	0.87
Tank washing	0.11
Flue cleaning	0.10
Inspecting	0.15
Firing-up	0.16
Engine house laborers	0.16
Turning table	0.04
Clinkering	0.24
Supply men	0.12
Coaling engines	0.10
Sanding engines	0.11
Watching engines	0.18

29 The cost of service rendered freight engines on the same road during the year ended June 30, 1909, was 8.4 cents per thousand ton-miles.

AMERICAN LOCOMOTIVE TERMINALS

By William Forsyth, Chicago

Member of the Society

The most interesting example of American engine house practice is that in the classification yards of the Pennsylvania Railroad at East Altoona, Pa. Here the traffic from three divisions of the road is concentrated, classified and despatched. The freight tonnage passing through this terminal is claimed to be the largest handled by any single system of freight yards in the world. The total capacity of the yards is 10,500 cars.

2 The eastbound traffic is composed largely of loaded coal and coke cars, and the number of cars handled per month in this direction is: loaded, 61,308; empty, 1306; total, 62,614. The westbound movement is composed largely of empty cars, with a total of 62,877 cars per month. In 1906 an average of 90 trains per day was received from the Pittsburg division and 60 from the Middle division, and the movement in one direction reached as high as one train every ten minutes for six hours. During the month of November 1909, the engine movement at this engine house was as follows:

Average number of locomotives despatched east and west in 24 hours	243
Maximum number despatched in 24 hours	290
Maximum number despatched in one hour including switch engines	40

3 The trains are operated by consolidation locomotives, and on account of the grades on the eastern slope of the Allegheny mountains westbound trains require three engines, two in front and one as a pusher. Eastbound, the line follows a comparatively light gradient along the Juniata river, and here large trains can be handled by one consolidation engine. There are 35 switch engines, requiring 70 engine crews for day and night operation. During the month of

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November 1905, there were handled over the ashpit a total of 6497 engines. The number of men employed in the yards is 1830. The number of engine men employed during the month averaged 1012 and the number of men employed about the engine house, shops and coal wharf and on the motive power roll was 700.

4 Near the center of the length of the terminal (Fig. 1) is located a large engine house, with ashpits, coal wharf, sand supply, a good-sized machine shop, storehouse and office, with bunk rooms overhead; also a power house, a fan house for heating, an oil house, and a toilet and locker house.

THE ENGINE HOUSE

5 The engine house is in diameter and cross-section the largest structure ever erected for this purpose. It has an exterior diameter of 395 ft. and a turntable of 100 ft. There are 52 stalls 90 ft. deep. The main portion of the house is 65 ft. wide and 30 ft. high. On the outer circle there is a lean-to 25 ft. wide and 18 ft. high. The engines head in toward this lean-to and the smokejack is located alongside the main columns at the outer portion of the main building. The main portion of the house was made 30 ft. high to accommodate a traveling crane, but columns for supporting the crane have not been erected, as jib cranes secured to the main columns were found more desirable. A cross-section of this engine house is shown in Fig. 2.

6 The turntable is operated by an electric motor. There are four drop tables, also operated by electric motors, two of them for driving-wheels, one large table for all wheels except the engine trucks, and another for pony truck wheels.

7 The coal wharf is a large structure arranged with a trestle approach having a grade of 3.88 per cent. The coal is dropped from hopper cars directly into bins and no cover is provided for the cars, as they are emptied entirely by gravity and no men are employed in the unloading. The storage structure is 32 ft. wide and 216 ft. long. A special gate and hood are used for regulating the flow of coal from the pockets to the tender. A steel gate drops below the floor of the pocket and is operated by a compressed-air cylinder.

8 At one end of the coal wharf is a sand house, where sand is dried in large stoves and descends through a grating to a reservoir, from which it is elevated by compressed air to the sand bins overhead, and flows by gravity to the engines.

FOLDER No. 2

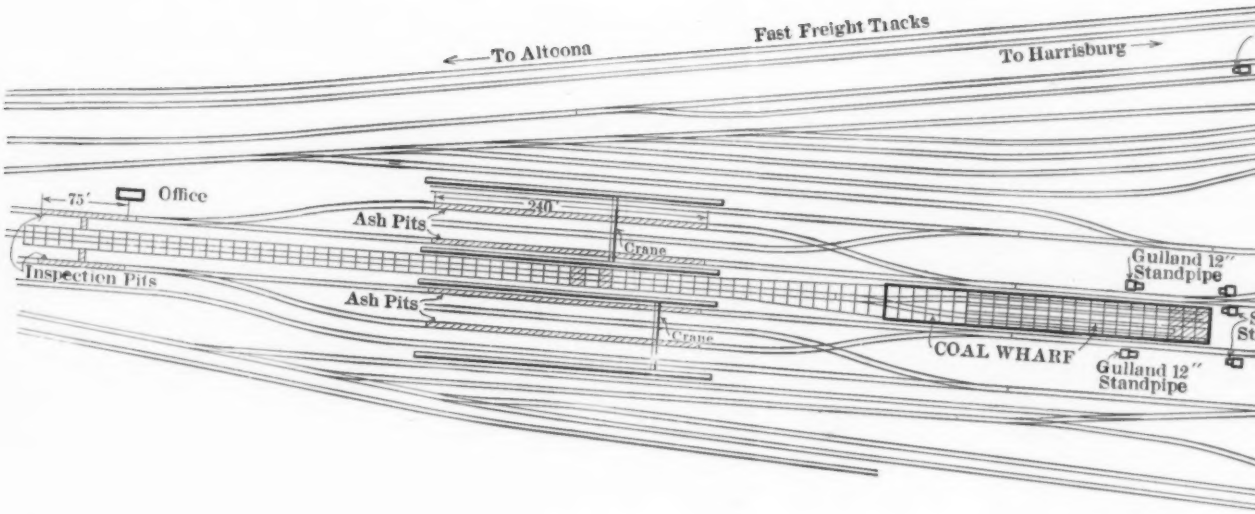
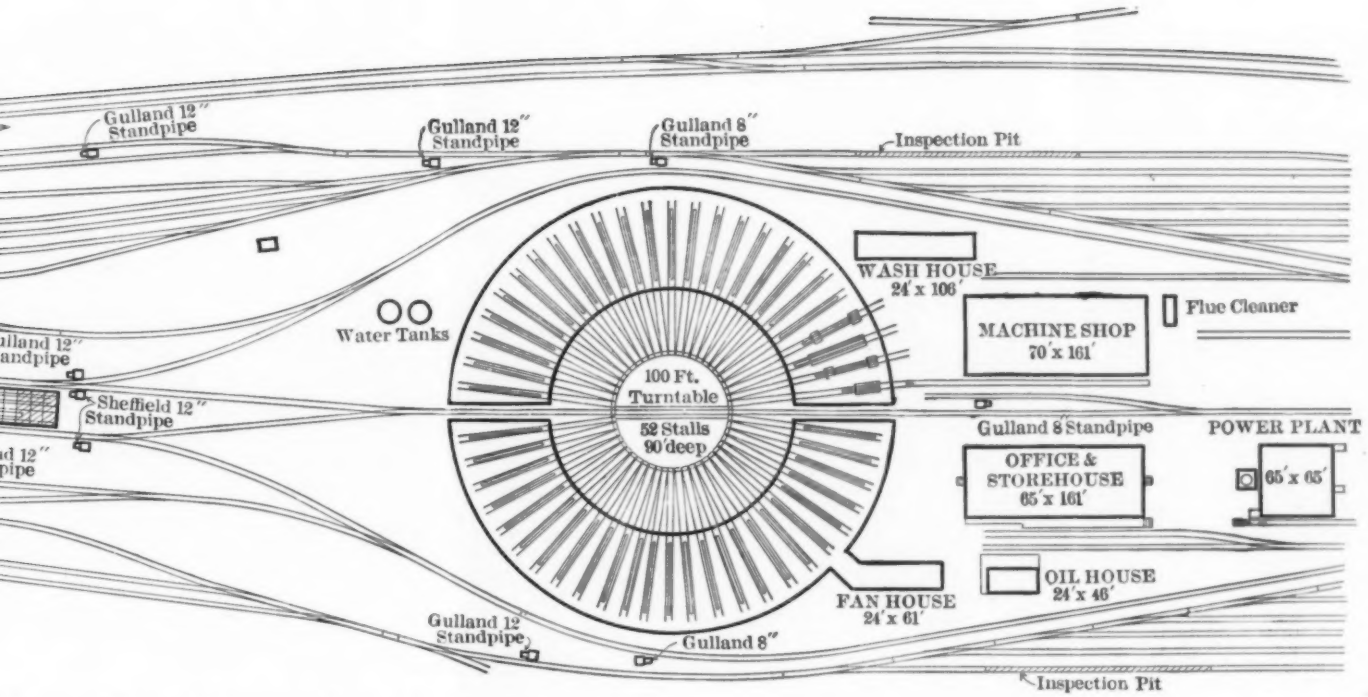


FIG. 1 GENERAL PLAN OF EAST ALTOONA



ALTOONA ENGINE HOUSE AND AUXILIARY STRUCTURES

9 Near the approach to the coal wharf are four ashpits, each 240 ft. long, two on each side of the wharf incline. Each pair is operated by an overhead 5-ton electric crane which spans four tracks, two of them over the ashpits for ash cars. Ashes are dumped from the engines into steel buckets which run on wheels on a track in the

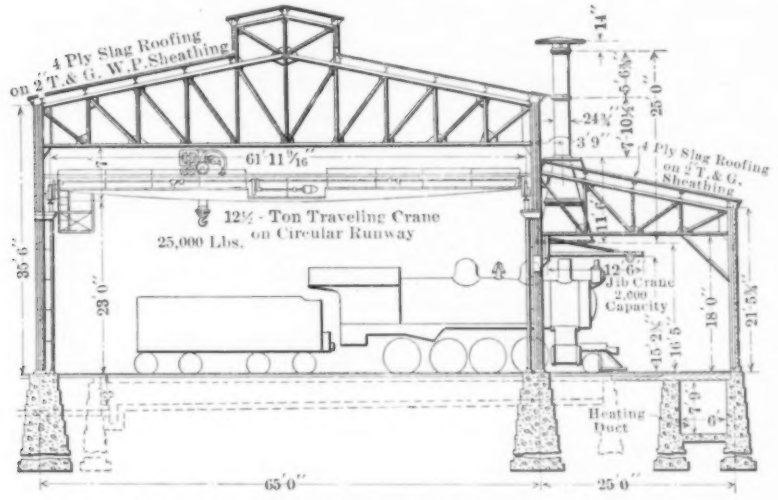

4 Ply Slag Roofing on 2" T. & G. W.P. Sheathing
61' 11 5/16"
12½ - Ton Traveling Crane 25,000 Lbs. on Circular Runway
4 Ply Slag Roofing on 2" T. & G. Sheathing
12' 6" Jib Crane 2,000 Capacity
Heating Duct
35' 6"
23' 0"
65' 0"
25' 0"

FIG. 2 CROSS-SECTION OF ENGINE HOUSE AT EAST ALTOONA, PA.

ashpit. These buckets are elevated by the crane and transferred to the ash car, where they are dumped. Beyond the ashpits at the extreme end of the coal wharf are inspection pits, 80 ft. long and 3 ft. deep, and connected by an underground passage extending under the coal wharf track.

ENGINE HOUSE ORGANIZATION

10 The work performed in an engine house includes almost everything in connection with locomotive repairs that does not require the locomotive to be sent to the general repair shop. No attempt will be made to itemize these repairs. The work which must invariably be performed periodically consists of boiler testing every six months; boiler washing, from once a week to once a month as necessity arises; staybolt testing each week; examination of smoke-box, draft arrangements and ash pans, each week; testing steam and air gages each month; washing tenders each month;

gaging height of pilots each week; gaging tank water scoops each trip; testing air brakes each trip; draining main reservoirs each week.

MANNER OF REPORTING AND PERFORMING DAILY WORK

11 When a locomotive arrives the first information the organization receives as to work necessary is in the engineer's report which he delivers at the inspection pit when the locomotive is turned over to the inspectors. Five inspectors are here employed, as the work must be done thoroughly in a minimum time, so that the hostler can move the locomotive to the ashpit and make room in the inspection pit for other locomotives waiting. One inspector examines the under-part of the locomotive and tender; one on each side inspects the outside parts, such as driving wheels, rods, steam chests, guides, crossheads and Walschaerts valve gear; there are two air-brake inspectors, one to operate the brake valve and inspect the fittings in cab and air pump, and the other to inspect all other parts of the air and sanding equipment.

12 All defects found by the inspectors are entered upon regular blanks and transmitted, together with the engineer's report, to the gang leader in charge at the inspection pit, who decides whether it is necessary to send the engine to the house or whether the repairs are so slight that they can be made on the outside repair pits in connection with the outbound storage tracks. His decision is marked upon the report, and upon the steam chest of the locomotive, and the reports are forwarded to the work distributor's office by pneumatic tube in 45 seconds. This saving in time over the 10 minutes ordinarily required by messenger is a decided advantage to the work distributor, as he is able to assign the work to various gang leaders, and have the necessary material ordered, before the locomotive arrives in the house or on the engine track.

13 While the inspectors are at work the lamps and torches are filled and trimmed by two lamp fillers. There is no further necessity for the engine house force to open the tool boxes, which are locked bythe engineer, and the keys, together with his time card, delivered to the engine despatcher at the foreman's office. The engineer is then relieved of all responsibility and of the care of the locomotive.

14 The engine moves from the inspection pit to the ashpit, where the firebox, ash pan and smoke box are cleaned. It then moves to

the coal wharf, where the tender is filled with coal; and a little farther on reaches the sand house, where it receives a supply of sand and water. It then moves into the engine house or to the outbound storage tracks, as necessity requires. If it goes to the engine house the track number and the time of arrival are reported by telephone by the turntable motorman to the work distributor, who by this time has the work which was reported by the inspector and engineer subdivided and assigned to various gangs. After completing the work these gangs report the locomotive ready for service to the engine house office, where arrangement is made for the movement of the locomotive to the storage siding to await assignment to a train. If the locomotive does not go to the engine house it is moved directly from the sand house to the storage siding, and the necessary work is assigned to a gang located on the storage tracks to make light repairs, after which the locomotive is reported ready for service.

ENGINE TRACING

15 At East Altoona there are sometimes as many as 200 locomotives within the engine house jurisdiction and it was found necessary to inaugurate some efficient method of locating them exactly at all times, so that men sent to make repairs will have no difficulty in finding any particular locomotive required. This is accomplished by telephone. Each time a locomotive moves to another locality the engine tracer in the foreman's office is advised as to where it came from and where it has been delivered, giving the number, the location on the track and the time in each case. When traffic at East Altoona is normal the engine house must deliver ready for service one locomotive every five minutes during the whole 24 hours of the day, as the engines for three divisions are here concentrated. It is vitally important that everything should run in absolute harmony as any interruption in this rapid flow would quickly result in a congestion on the road.

ENGINE DESPATCHING

16 After the engine tracer has been advised that a locomotive is placed on the storage track for service, he informs the engine despatcher, to whom the crew callers report. The engine despatcher is also in touch with the yardmaster and is the middle man between

the engine house foreman and the yardmaster. As soon as the yard master receives information that he needs a locomotive and crew for a certain train of a given class at a certain time, he advises the despatcher, who immediately calls out a crew, and when they arrive assigns to them the locomotive selected, which is standing on the outbound storage track. A telephone system has been installed whereby all crews may be called. The houses of the engine men have been equipped with telephones connected with the engine house office, an arrangement which dispenses with messengers and enables the crews to be called very promptly.

17 The fireman usually arrives first, and after receiving his time card and keys he takes charge of the locomotive, relieving the engine watcher of any further responsibility, and immediately prepares a fire for road work. The engineer, upon arrival, after receiving his time card at the engine house office and inspecting the bulletin board to read any new orders, goes to the locomotive and oils the machinery, and then waits until he is given the proper signal to move out of the storage yard. The crews are usually called in sufficient time to prepare the locomotive properly for road work prior to leaving the storage track.

ORGANIZATION OF STAFF

18 For the operation of this locomotive terminal an elaborate organization has been worked out, based upon the principle that none but the heads of sub-departments shall report to or receive instructions from the foreman, his assistant or the work distributor. The responsibility of supplying material and the supervision of the workmen are placed directly upon these gang leaders, who are foremen of their respective gangs. Certain questions of discipline must be handled by the foreman personally, but questions relating to rates of pay, transfers, discipline, etc., ought to originate with the gang leaders, and their duties not be confined to giving out work to the men after the distributor has assigned it. This results in successful operation, but it also gives some dignity to the position of gang leader, and at the same time relieves the foreman of petty details.

19 The foreman of a large engine house should not be an ordinary shop man, but should have some outlook over and interest in the operating department. He should be a good disciplinarian, commanding the respect of his men, should display clear judgment and

form conclusions quickly. He should be a good all-round organizer and capable of taking care of business promptly during rush hours. He should know how to make brief and intelligent reports and possess mechanical ability. He should be broad-minded enough to recognize that there is a commercial side to transportation, and should not be overburdened with office work. His assistants should possess sufficient ability to decide what work may be slighted or not done at all, and a locomotive still be safe to make one or more round trips.

20 The engine house foreman receives from the division master mechanic instructions pertaining to such matters as the number of men required, rates of pay, discipline, maintenance of his entire plant, and standards. He receives from the division superintendent instructions relating to crews and despatching of locomotives, and carries out such discipline of the engine crews as may be imposed by the division superintendent through the road foreman of engines. He must coöperate with the road foreman of engines concerning the condition of power and its performance on the road, and the amount of coal and oil consumed. He must carry out orders issued by the road foreman of engines concerning the assignment of locomotives and crews. At East Altoona the engine house operation is a continuous one throughout the day and night, and the night force is practically the same as the day force.

21 Reporting directly to the engine house foreman are the *assistant day foreman and assistant night foreman.* Reporting to assistant foremen for office work are the *first clerk,* who takes all the foreman's and the assistant foremen's dictation, and the *second clerk,* who has charge of all messengers and ordinary clerks who may be engaged in computing the time and earnings of the men and in getting together all the information required by the master mechanic's shop clerk and for properly keeping the records. Next in order is the *engine despatcher,* to whom report the *engine tracer,* the *callers* and the *clerks* who keep the records of engineers and firemen and of locomotives arriving and departing. The engine despatcher marks up the crew board, issues time cards to engine crews going out, and accepts and approves them upon their return.

22 Next in order reporting to the assistant foreman are the various *gang leaders.* First is the gang leader in charge of the machine shop. The work of his men is confined to machine and vise work, and they are not called upon to leave the machine shop and make repairs in the locomotive shop or storage yard except in cases of emergency. Their work is chiefly preparing and fitting the repair parts which

the engine house employees apply to the locomotives. The gang leader in charge of the blacksmith shop has charge of all smiths and helpers, as well as the forces of flue welders and laborers in the engine house engaged in piecing flues and preparing them for locomotive boilers. The gang leader of the power plant has full charge of stationary engineers and firemen, electricians and wiremen. Another gang leader has charge of the ordinary helpers and sweepers in the engine house, who keep the shop property clean.

23 The foreman in charge of all employees actually handling locomotives, from the time they arrive at the terminal until they are turned out, also of all workmen engaged in the engine house or storage yard, is called the *work distributor*. Clerks reporting to his two *assistants* receive the engineers' and inspectors' work reports and copy the work required on slips of paper numbered consecutively and properly dated. These slips are then delivered to the gang leaders of the men who perform the work.

24 The men composing the gangs working on a piece work basis are divided into pools of three or four men, with leaders. The *pool leaders* are under the direction of gang leaders. When the earnings of three or four workmen are pooled it is found that each man is determined that the others should perform their fair share of work, and in case one man fails to do this the remainder insist that the lazy or careless workman be taken out of their pool.

25 The gang leaders at the inspection pits are in charge of *inspectors, lamp fitters and engine preparers,* who handle the locomotives between the inspection and ashpits.

26 There are three *assistant gang leaders* in charge of the *engine preparers.* Assistant No. 1 has charge of all work in cleaning fires and placing the locomotives in the engine house or storage yard and of *the ashpit men and crane operators* who load cinders. Assistant No. 2 has charge of the *coal gagers and sand house men, turntable operators* and men engaged in handling locomotives from the engine house to the storage yard. Assistant No. 3 has charge of the men handling locomotives in the storage yard and despatching them when ordered for service, including *engine watchers, switchmen and engine timers.*

27 Next reporting to the work distributor is the *gang leader of boiler washers,* whose men wash out the tenders, blow out, wash, fill and fire all boilers, and watch locomotives until they are removed from the engine house. Next is the *gang leader of staybolt inspectors,* whose men test staybolts and examine fireboxes and tubes. There

is a *gang leader of boiler makers*, engaged in renewing tubes and staybolts, patching, testing and calking tubes, and general boiler work. A *gang leader of engine cleaners* has charge of men cleaning locomotives and tenders. There is a regular schedule for doing this work, and it is so arranged that the work is performed when the locomotives are receiving staybolt repairs or boiler washing. A *gang leader of spongers* is in charge of packing journal boxes and other work relating to lubrication. In the engine house there is a *gang leader of machinists*, who are engaged in setting valves, renewing packing and all other general machinist work on the locomotive proper. The *gang leader of tank repairs* is in charge of repairs to tenders, frames, tanks and couplers, of renewing truck wheels, and other tender repairs. The *gang leader of air-brake repair men* keeps in order the air brakes and sanding equipment.

28 The gang leaders of men on piece work should have not more than ten or twelve men under them, with the exception of the gang on boiler work, which may require from one to four days to complete.

POOLING LOCOMOTIVES

29 Improved engine house facilities, more system and better organization are favorable to the pooling of locomotives, and this practice has become more general for freight engines in the United States. As recently as in 1905 the reports on pooling presented at the International Railway Congress indicated that pooling was not used on the majority of railways in the United States under normal conditions of traffic. The large increase in traffic in proportion to the number of locomotives in 1906 and subsequent years has compelled most of the roads to resort to the pooling of freight engines and the double-crewing of passenger engines, and these methods are now well established on the majority of American railways. By improved methods the operations of cooling down, washing, and filling with hot water may be performed in less than two hours without injury to firebox and tubes, and this alone has contributed in a large measure to the success of pooling. The reduction in boiler pressure from 225 lb. to 160 and 180 lb. has also reduced the number of boiler failures and permitted the more continuous use of locomotives which results from the pooling system.

30 The amount of work which the engineers and firemen do at the engine houses is now so small that it is almost confined to lubrication of machinery and inspection of tools and supplies on engines,

and no dependence is placed on them for repair work. The engineer is required to report any defects or needed repairs which he observes while running the locomotive or by casual inspection on the outside. The machinery underneath is inspected by men regularly employed for that purpose, and inspection pits in the tracks approaching the engine house are now regarded as an essential of a modern locomotive terminal. With the changes in practice above indicated, the pooling of freight engines is rendered more successful and satisfactory and its effect on the cost of locomotive repairs is not so pronounced as formerly.

31 On some railways where shop facilities are limited, locomotives are required to make a large mileage before they go in for general repairs. The principal items which send engines frequently to the shop are worn tires, defective tubes, and, perhaps, worn driving boxes. At some engine houses all these repairs are made, the worn tires being replaced by new ones or by others which have been turned at the shop. In this way such machinery as rods, crossheads, guides and link motion, is kept in service, so that passenger locomotives make as high as 127,000 miles, and freight locomotives, 100,000 miles between general repairs, one passenger locomotive making 256,000 miles between shoppings. Passenger locomotives average 120,000 miles and freight locomotives, 95,000 miles.

32 On the Chicago, Burlington & Quincy for the last six months of 1909, pooled freight engines made on one division as high as 4167 miles per month and 110 engines on three divisions averaged 3777 miles per month. On other roads passenger engines double-crewed make an average of 6500 to 7500 miles per month, one road reporting for engines in express service 418 miles per day and 12,780 miles per month.

HANDLING ENGINES

By H. H. Vaughan, Montreal, Can.

Member of the Society

The desirability of pooling engines in place of operating them by regularly assigned crews depends, in the writer's opinion, on whether the engines are engaged in passenger or freight service, and in the latter case, on the conditions which exist.

PASSENGER SERVICE

2 Where traffic conditions admit of the engine making greater mileage than can properly be run by one crew, two crews assigned to one engine, or three crews to two engines, will enable the engine to make as great a mileage as is desirable. On account of the comparatively short time occupied from terminal to terminal, the crews can usually make a round trip without holding the engine longer than is required to handle it and prepare it for the return trip or to await its train. By using more than one crew to the engine, it is theoretically available on its return just as soon as though it were pooled. In practice, unless pooling is carried to the extent of sending out any engine on any train, certain engines are regularly used on certain trains or groups of trains, and it is comparatively easy to arrange the crews and engines so that a reasonable time may be allowed for repairs and yet ample service be obtained from the engine. When working with assigned crews it is of course usual to employ some extra passenger men to take the place of the regular men, who are also available in case an extra trip is required from an engine on account of specials or extra sections of regular trains. Where regular scheduled trains have to be provided for, this system is as flexible and convenient

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as pooling and has the additional advantage in passenger service that the men run certain trains regularly, and will consequently give better service than when handling a number of trains indiscriminately.

3 Pooling in passenger service probably does not require much discussion. The system is not in extensive use and will presumably have few advocates. The writer would, however, state as a result of his experience with both pooled and assigned engines in passenger service, that he is most strongly opposed to pooling in this service and considers that far better results can be obtained from assigned crews.

FREIGHT SERVICE

4 Here conditions are very different. The time is slow and a long time is occupied from terminal to terminal, so that crews may require a full allowance of rest on arrival, or may even have to be relieved on the road. Few, if any, of the trains run at regular hours, and in place of following a defined schedule, the demand for engines varies with the traffic. When business is heavy, engines are wanted as soon as they are repaired and ready for service, making it difficult, if not impossible, to select the engines in any particular order. By pooling, such difficulties may be more easily met, especially at large terminals. When engines are assigned the practice usually required by the agreement with the men is that engines shall be prepared and despatched in the order in which they arrive, but if the engine is ready its use may be retarded by the time required by the crew for rest. In pooling, both these objectionable conditions vanish. An engine may be turned at once if fit for service and thus rendered immediately available, and the movement of the men being entirely independent of that of the engines, the detention of engines at a terminal can be regulated by simply increasing or decreasing the number in the pool.

5 Under such conditions, if pooling is not carried on in name, it will be in fact, simply because business can not be handled unless engines are used without reference to the order of their arrival. Granted therefore that pooling is advantageous under these conditions, it should be done properly. All the features necessary to a successful pooling system must be employed, such as thorough terminal inspection independent of the engine crews, and arrangements for handling tools and engine supplies, and caring for headlights, oil cups, etc. If pooling is resorted to when business is especially heavy, or

when traffic is disturbed by storms or by other causes, without proper arrangements being made, the results are most objectionable. Under these circumstances, the condition of the power will depreciate rapidly and the service rendered will be exceedingly inefficient. The maxim is frequently stated, "If you pool, pool," and its wisdom has been demonstrated by experience. The real question about pooling is therefore whether there are conditions under which it is preferable to adopt the alternative practice, that of running engines with assigned crews. This depends on the results obtained from the two systems, which are in the writer's experience as follows:

6 *Mileage.* It is possible to obtain somewhat greater average mileage per engine under the pooling system, but the increase does not exceed ten per cent when traffic is being handled smoothly and without excessive congestion and delays.

7 *Repairs.* When running successfully under the assigned engine system, repairs are less than when similar conditions exist with pooled engines. A man running an engine regularly keeps up the smaller details and knows what work is required at once, and what must be looked after in due time. His inspection reports are more reliable than those of a man who has had an engine for one trip only. As he has to run the engine next trip as well, he will handle it with greater care and avoid any action that will cause him trouble in the future. Men who have been accustomed to running pooled engines will not do all this at once, but they most certainly will if assigned to an engine for any length of time, and the difference is noticeable in engine houses where some engines are assigned and some are pooled.

8 Engines are sometimes taken care of by the headquarter station system, the work required to maintain the engine in proper condition being done at the terminal designated as the home station, while at the other terminal the only work done is that necessary for the return trip. With this arrangement, even with pooled engines, the same crew will, if possible, make the round trip; but when they are changed, practically as much work is required at the away station as at the home station. The result is a considerable increase in the cost of repairs, for there is not as a rule very much difference in the cost at the home station.

9 When the assigned engine system proves inadequate for traffic demands, the results change. Men will endeavor to book enough work against the engine to hold it until they have rested, and on the other hand engines are liable to be wanted before repairs that are actually required are completed. Under these conditions engines may be bet-

ter and more cheaply maintained when pooled; but under normal conditions the writer's experience would show that with assigned crews the cost of running repairs may be reduced five to ten per cent and better mileage obtained from the engines between shoppings.

10 *Fuel.* It is almost impossible to determine the fuel consumed by an engine on an individual trip, and consequently difficult when pooling to keep any record of the amount of coal used by different men. A record may be kept by engines, but it is then impossible to locate the responsibility for any excessive consumption. The practical result is that on pooled engines, individual fuel records are of comparatively little use. With assigned engines, while trip records may not be individually accurate, the average of several consecutive trips soon becomes so, as the variation of the amount of coal left on the tender, while important on one, is of comparatively small importance on a number of trips. There is no doubt in the writer's mind that individual coal records, whether by trip or by period, are an important factor in obtaining economical results in fuel consumption, both from men and from engines, and he ascribes the good results that have been obtained on the Canadian Pacific Railway largely to the careful way in which the records have been watched.

11 Apart from the records, the familiarity of the men with the engines has an important bearing on fuel consumption. Most engines vary slightly in the way they burn the coal, in the nature and intensity of the draft, and in the best position for the throttle and reversing lever. Crews knowing an engine thoroughly learn about these peculiarities, while they do not when running a different engine each trip. One crew will obtain from an engine results that are impossible for another crew, and thus the result with assigned crews is a tendency to higher efficiency than when every engine has to be drafted and adapted to do the work with the poorest crew on the division. It is only necessary to watch the difference in the way an engine is handled by a regular crew and by a pooled crew, to realize the advantage of the former, and important results have been clearly shown with the same men and engines, on divisions where the two systems have been in effect.

12 *Service.* The remarks that have been made in connection with repairs and fuel apply with almost equal force to the class of service obtained from the engines, with reference to failures, breakdowns and ability to make the time required. A crew that knows the engine will get more out of it than one that does not. They will notice any difference in its working and will take more interest in getting

any defect rectified. They will keep their equipment in better condition and will pay more attention to bearings which show signs of heating, etc. All these conditions lead to better and more efficient service.

13 *Engine House Expenses.* Inspection, the care of tools, the filling of lubricators, headlights and cab lamps, are commonly looked after on assigned engines by the crews. When engines are pooled this work has to be done by the engine house force. At a large terminal this expense is not large, but when the number of engines handled is small, it is difficult to arrange the duties of the men doing this work to prevent its becoming a serious item. Conditions vary on different r oads in this respect, but the fact remains that this work is not in any way burdensome to men having a regular engine, while it is burdensome if they are required to prepare a different engine each trip, and consequently they object to it very strongly. In the majority of cases this work constitutes an additional charge on engines that are pooled.

CONCLUSION

14 In conclusion, the writer considers that in passenger service pooling is objectionable under any conditions and should be avoided if possible.

15 In freight service, pooling is advisable if conditions are such that engines cannot be run with assigned crews, and probably on divisions where business is so heavy that sixty engines per day or over are despatched from the terminal; but the writer's experience is that where assigned crews can be used on engines, the cost of repairs, the amount of fuel consumed, and the class of service obtained, will all be more satisfactory.

16 He therefore regards pooling as a practice that may be necessary under certain conditions, but that is certainly not desirable if the alternative system can be satisfactorily carried out.

A REGENERATOR CYCLE FOR GAS ENGINES USING SUB-ADIABATIC EXPANSION

By Prof. A. J. Frith, Chicago

Member of the Society

Some confusion has arisen in thermodynamic problems from the tendency of many older writers to assume ideal conditions and carefully work out problems to their legitimate conclusions without regard for the losses that inevitably exist in a practical installation. While it may be difficult to determine the extent of their influence, it will clarify the conclusions if such losses are pointed out even approximately, and help dispel the popular belief that theory and practice are incompatible in the internal combustion engine.

2 An ever new and interesting problem is that of how far, commercially, economy of fuel can be carried in the gas engine. In the direct-expansion engine it has been proved theoretically and practically that an increase of compression reduces the fuel consumption, and this precompression has in some instances reached a commercial maximum. High pressures, however, entail heavy flywheels and finely finished valves and joints, require operators of greater ability and otherwise tend to increased expense of maintenance, all of which it would be commercially desirable to eliminate. But how can it be done?

3 Thermodynamics has shown that there is theoretically another method of operating prime movers: namely, on regenerative cycles. These cycles which are later described in this paper, have a theoretical economy as high as the Carnot cycle, the ideal cycle of expansion engines; and for gas engines have the great advantage of a high mean effective pressure, when the Carnot cycle is attenuated and weak.

4 Engines operating on regenerator cycles, however, have not come into use, despite numerous patented designs, which would lead

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us to suspect that from a practical standpoint there is a fallacy in them, though there is no hint of it in the theory founded on ideal conditions.

5 It appears curious that the principle of regeneration, so highly successful in metallurgical and gas-burning installations, which is present in its essence in every boiler plant and in most cases of the transfer of heat and is absolutely essential in hot air engines, noted for their ease of operation, is described as inapplicable to the internal combustion engine.

6 What is the reason for this reversal of judgment in the case of the internal combustion engine? Investigations show that under actual operative conditions the engine cylinder must be water-cooled and that the contact of cool surfaces with incandescent gases withdraws a large percentage of the heat developed by the fuel. Thus, in a test quoted by H. A. Golding, a heat balance shows that

The heat to water cooling = 39.4 %
The heat to exhaust = 37.8 %
The heat to i.h.p. = 22.8 %

or that this loss of water cooling amounts to nearly 200 % of the power developed.

7 Whatever other conditions control this source of waste, we can consider it to vary as the difference between the average temperature of the burning charge and the temperature of the cooler walls. In this particular test the temperature of the charge may have been as high as 2800 deg. fahr. at the peak of explosion and 1500 deg. at the point of release, or an average temperature in the neighborhood of 2150 deg. With water cooling, even as high as 200 deg., there would be a difference of 1950 deg., causing a water loss of 40 %.

8 Now regenerator cycles all depend upon the passing of the gases through the regenerator during the exhaust and to make them most effective the temperature must be kept as high as possible to the very end. For example, if the temperature were 2800 deg. both at the commencement and end of the stroke, giving an average temperature of 2800 deg. and a difference of 2600 deg. with 200 deg. water cooling, there would be a water loss of, roughly,

$$\frac{2600}{1950} \times 40 = 50\ \%$$

chargeable to all the heat in the cycle. Part of the heat is regenerated, however, so that all the loss must fall on the balance; that is, be supplied by combustion. This raises the loss to 56 % and while

correct theory may show the exhaust loss to be only say, 22 %, the heat balance for the regenerator cycle becomes, practically, as follows:

Heat to water loss = 56 %
Heat to exhaust = 22 %
Heat to i.h.p. = 22 %

9 Thus we see that the high constant temperature of expansion in the older regenerator cycles causes an excessive loss of heat to the water-cooled surfaces, and is in itself sufficient to account for the failure to realize in practice the degree of economy expected. This seems to have been unrecognized by designers, who not only fail to provide means for mitigating this evil, but as is most frequent in patented designs, favor burning the gases to volumes greater than that of the original charge, in the largest cylinders possible. By this means the loss to the water-cooled surfaces is increased and it

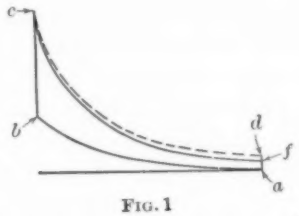


FIG. 1

THEORETICAL GAS ENGINE CYCLE

is not surprising that poor results followed their efforts. In spite of this every regenerator cycle within our knowledge includes constant temperature compression and expansion.

10 There are some other defects of the regenerator itself; thus, if its efficiency is to be very high it must be bulky, with large clearance, though this trouble practically disappears when the efficiency is moderately high, but successful results depend upon delivering an exhaust of comparatively low temperature, and as the regenerator is the only means provided for that purpose in this cycle, moderate regenerator effect is for our purpose inoperative.

REGENERATOR CYCLE WITH SUB-ADIABATIC EXPANSION

11 Attention is now directed to a new regenerator cycle with *sub-adiabatic expansion* which avoids the defects mentioned and which theoretically and practically promises unusual results. If, in Fig. 1, we have a card similar to an ordinary gas engine card, we recog-

nize the compression *ab*, the explosion *bc*, the expansion *cd* and the exhaust *da*. We know that the efficiency of this cycle, afterwards modified by the degree of water loss, equals the heat supplied during *bc*, less the heat rejected during *da*, divided by the heat supplied during *bc*.

$$\text{Eff.} = \frac{H - exhaust}{H} = \frac{area}{H}$$

Roughly, the degree of water loss depends on the average temperature during expansion. In previous regenerator cycles it has been from the *exhaust gases* that heat has been extracted by the regenerator. What happens if it is from the expanding gases that the regenerator absorbs its heat?

12 If, in brief, during the expansion *cd*, the burning gases pass through the regenerator, and are cooled thereby, evidently the pressure will fall more rapidly than by free expansion, say according to a line *cf steeper* than the adiabatic line, and the heat rejected by the exhaust *fa* is evidently less than the exhaust *da*, while if this heat abstracted by the regenerator is added to the explosion line *bc*, less heat is thereby required by burning to reach the pressure *c*. Let F = % of heat regenerated; then the heat supplied by burning = $(1-F)$ *bc* and

$$\text{Eff.} = \frac{\text{area of the card in B.t.u.}}{(1 - F)\ H}$$

which becomes larger as F increases to its higher values.

13 As the degree of regeneration increases, the point *f* must approach *a*, the pressure, volume and temperature of the original charge, where no heat would be rejected in the exhaust and the efficiency would be a maximum. It is also noticed that the *average* temperature of expansion *cf* lying below the line of free expansion is less than that of the regular card and far less than that of the constant temperature expansion of the other regenerative cycles. Hence, the per cent of heat loss by water-cooling, in what I have called the Frith Sub-Adiabatic Regenerative Cycle, should be lower for all the heat present than by the method mentioned, and when charged to heat developed by burning is still less than that charged to ordinary cycles.

14 The method by which the per cent of heat loss through cooling is determined may form the subject of another communication when checked with a number of engine tests. The calculations indicate, however, after checking the results with the inferences drawn from

tests of boilers by the United States Geological Survey, that the per cent of heat loss is not directly proportional to the number of square feet of surface. Similar methods show that the regenerative effect may be expressed in per cent of heat or temperature available; that is, in per cent of the difference between the temperature of the cooler gases passing into the regenerator and that of the hotter gases returning through the regenerator. This percentage again does not directly depend upon the amount of surface.

15 To recapitulate, the regenerator cycle hitherto known (Fig. 2) is an ideally perfect cycle, but besides requiring a 100 per cent regenerator, the cycle under practical conditions entails an excessive loss of heat by water cooling, and its line of expansion at constant temperature is flatter than that of free expansion and represents *expansion with the addition of heat.*

16 The regular gas engine cycle (Fig. 3), ideally treated, has an expansion line coincident with that of free expansion, entails ordinary

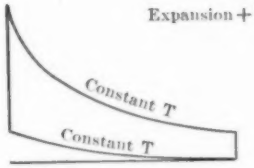


FIG. 2

CONSTANT TEMPERATURE CYCLE

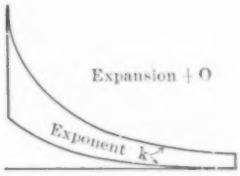


FIG. 3

ADIABATIC CYCLE

loss of heat to water-cooling, and represents *free expansion without addition or subtraction of heat.*

17 The regenerative sub-adiabatic cycle, Fig. 4, requires, even for its maximum efficiency, regenerators of only practical efficiency. Its line of expansion, steeper than the line of free expansion, entails ordinary, if not less, loss of heat to water cooling and represents *free expansion with the subtraction* of heat.

18 The discussion of this line of expansion seems not to have been treated by writers on thermodynamics and if this is so it is a new cycle of operation. A comparative estimate of the various cycles with moderate compression and a mechanical efficiency of 80 per cent, including the Diesel oil engine, is as follows:

ESTIMATED HEAT BALANCE OF VARIOUS CYCLES

Type	Compression Absolute	Water Cooling Per cent	Exhaust Per cent	i.h.p. Per cent	Mech. Eff. Per cent	Brake Eff. Per cent
Regenerative cycle; expansion $+H$		56	22	22	80	17.6
Diesel engine	515	35	28	37	76	28
Regular gas engine; expansion $+O$	140	35	38	27	80	22
Sub-adiabatic regenerative cycle 65% regenerator; expansion $-H$	140	30	25	45	75	34

19 We now desire to obtain a rational expression for the efficiency to be expected in a sub-adiabatic regenerator cycle, treating it as for air. It is evident that it depends not only on the compression, but also on the degree of regeneration used, remembering that for any point as P_1, Fig. 5, the heat in 1 lb. of mixture equals the area under the line of adiabatic expansion, with the exponent k, if it be carried to the line of no pressure.

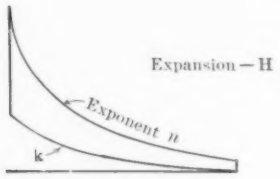


FIG. 4

FRITH SUB-ADIABATIC REGENERATIVE CYCLE

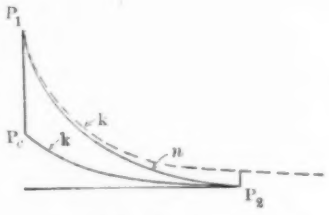


FIG. 5

FRITH SUB-ADIABATIC REGENERATIVE CYCLE OF MAXIMUM EFFICIENCY

20 The same is true for the point P_c. The difference in area between these two lines of complete expansion equals the heat furnished per pound, while the difference between the two lines at P_2 equals the heat rejected. Fig. 5 shows the condition of maximum economy, or no rejection of heat, and the line of expansion with an exponent n, steeper than free expansion, shows the effect of the heat withdrawn by the regenerator. The heat present at P_1 = heat regenerated + the heat represented by area under line n + the heat represented by area under line from P_2, exponent k. The heat-contents at any point as $P_1 = \dfrac{p_1 V_1}{k-1}$. If the charge be compressed adiabatically from P_2 to P_c, heat be added, partly by the regenerator, from P_c to P_1, expansion be from P_1 to P_2 with abstraction of heat by

the regenerator, it is steeper with its exponent n than free expansion, and the heat abstracted by a regenerator equals the heat given out when conditions are normal.

21 Let F = the per cent of heat available that is regenerated and $F^{\text{max.}}$ = maximum regenerator per cent available. Then,

$$\text{Heat added to the cycle per pound} = \frac{p_1 V_1}{k-1} - \frac{p_e V_1}{k-1}$$

$$\text{Heat added by the regenerator} = F\left(\frac{p_1 V_1}{k-1} - \frac{p_e V_1}{k-1}\right)$$

$$\text{Heat abstracted by the regenerator} = F\left(\frac{p_1 V_1}{k-1} - \frac{p_e V_1}{k-1}\right)$$

$$\text{Heat added by combustion} = (1 - \text{F})\left(\frac{p_1 V_1}{k-1} - \frac{p_e V_1}{k-1}\right)$$

$$\text{Heat under the curve} = \frac{p_1 V_1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right]$$

$$\frac{p_1 V_1}{k-1} = F^{\text{max.}}\left(\frac{p_1 V_1}{k-1} - \frac{p_e V_1}{k-1}\right) + \frac{p_1 V_1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] + \frac{p_2 V_2}{k-1}$$

Dividing by $\frac{p_1 V_1}{k-1}$

$$1 = F^{\text{max.}}\left(1 - \frac{p_e}{p_1}\right) + \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] + \frac{p_2}{p_1} \times \frac{V_2}{V_1}$$

from which

$$F^{\text{max.}} = \frac{1 - \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] - \frac{p_2}{p_1} \times \frac{V_2}{V_1}}{\left(1 - \frac{p_e}{p_1}\right)} \quad \ldots\ldots(1)$$

an expression for $F^{\text{max.}}$ when pressures of any particular case are given, for the value of $k = 1.405$ and

$$n = \frac{\text{Log } P_1 - \text{Log } P_2}{\text{Log } V_2 - \text{Log } V_1} \text{ (a well-known expression)} \quad \ldots\ldots(2)$$

Also

$$(1 - F^{\text{max.}})\left[1 - \left(\frac{p_e}{p_1}\right)\right.$$

$$= \left\{ 1 - \frac{1 - \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1}\right] - \frac{p_2}{p_1} \times \frac{V_2}{V_1}}{1 - \left(\frac{p_c}{p_1}\right)} \right\} \left[1 - \left(\frac{p_c}{p_1}\right) \right]$$

Reducing to

$$(1 - F^{\max.}) \left[1 - \left(\frac{p_c}{p_1}\right) \right] = -\frac{p_c}{p_1} + \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1} \right] + \frac{p_c}{p_1}\left(\frac{V_1}{V_2}\right)^{k-1}$$

Since $p_2 V_2^k = p_c V_1^k$ or $p_2 V_2 = p_c V_1 \left(\frac{V_1}{V_2}\right)^{k-1}$

and as

$$-\left(\frac{p_c}{p_1}\right) + \frac{p_c}{p_1}\left(\frac{V_1}{V_2}\right)^{k-1} = -\frac{p_c}{p_1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1} \right]$$

we have

$$(1 - F^{\max.}) \left[1 - \left(\frac{p_c}{p_1}\right) \right] = \frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1} \right] - \frac{p_c}{p_1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1} \right] \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Now the efficiency $= \dfrac{\text{work}}{\text{heat supplied by combustion}}$. Therefore

$$\text{Eff.}^{\text{Max.}} = \frac{\frac{p_1 V_1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1} \right] - \frac{p_c V_1}{k-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1} \right]}{(1 - F^{\max.}) \left(\frac{p_1 V_1}{k-1} - \frac{p_c V_1}{k-1} \right)}$$

Dividing by $\frac{p_1 V_1}{k-1}$ and substituting the values from Equation 3 we have

$$\text{Eff.}^{\text{Max.}} = \frac{\frac{k-1}{n-1}\left[1 - \left(\frac{V_1}{V_2}\right)^{n-1} \right] - \frac{p_c}{p_1}\left[1 - \left(\frac{V_1}{V_2}\right)^{k-1} \right]}{(1 - F^{\max.}) \left(1 - \frac{p_c}{p_1} \right)} = 1, \text{ or } 100\% \quad \ldots (4)$$

a result that is startling, when we realize that we have been taught

that the expression for efficiency $\left(\frac{T_1 - T}{T_1}\right)$, however high, can never reach unity with the condition of our problem, that if the expansion with the abstraction of heat can reach the pressure and volume of the original charge at p_2, the temperature must be that of the entering charge, then there is no loss of heat to the exhaust, and as there is no isothermal compression with its loss of heat, all the heat of combustion must be changed into work, and 100 per cent efficiency is the necessary result.

22 The expression (Equation 1) for the value of $F^{\max.}$ has been worked out for several conditions of practical compression and pres-

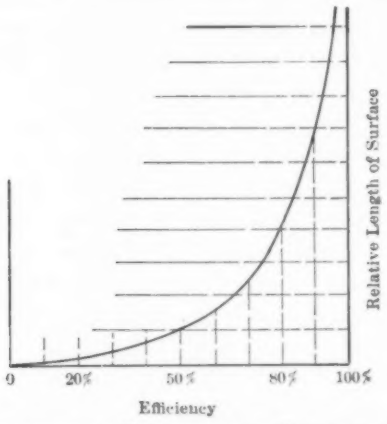


FIG. 6. VARIATION OF REGENERATOR EFFICIENCY WITH SIZE

sures and gives values between 72 per cent and 82 per cent for regenerator efficiencies, and we know that many regenerators are in use where these figures are exceeded. It may here be of interest to examine Fig. 6, which represents the variation of the efficiency of a regenerator with an element of its size.

23 The abscissæ in Fig. 6 represent efficiency, the ordinates length, and the diagram shows that the efficiencies increase very rapidly with the lower values, but the curve finally is an asymptote to the length, explaining the bulk of very high efficiency regenerators, while practical dimensions possibly reach their limit at the crest of the curve, at about 75 per cent, which is in favor of high cycle efficiency with practical construction.

24 We know that the lowest temperature of the regenerator itself must be higher than the temperature T_c, pertaining to P_c, Fig. 5,

and the returning gases issue therefrom at a still higher temperature. How, then, can the lower temperature of atmospheric exhaust be possible?

25 Remember that we use two cylinders, freely open to each other through a regenerator, and that Fig. 5 represents the change of volumes and pressures, for the whole charge, partly in one, and partly in the other cylinder. The pressures in each, at the same moment, must be equal; but the temperatures are not equal, one being that of the gases before they pass through the regenerator, and the other that of the gases after they issue therefrom. The pressures in Fig. 5 result from the combined temperatures of the entire charge volume. Remembering that the gases are returned through the regenerator progressively throughout the stroke, let us consider a small volume of gas that issues from the regenerator, early in the cycle. It is at a temperature due to the regenerator, and is lower than the average, indicated by Fig. 5, but it is at the pressure shown. If we consider this particle as expanding freely to atmospheric pressure, its individual temperature will be very low at exhaust. The contrary effect follows with a particle issuing at the end of the cycle. The actual temperature of exhaust is the combined effect of all the particles, each chilled to a different degree by its own rate of expansion after it has left the regenerator. Hence it is a fact that a portion of the gases repassing through the regenerator, at the high pressure of the early part of the cycle, are themselves at a lower temperature than the average temperature corresponding to that pressure. They are expanded from this high pressure to atmospheric pressure, after they have left the regenerator, and hence reach refrigerating temperatures, and temper the additions at lower pressures, in the final temperatures. This expansion being governed by two exponents n and k gives expression not easily reduced, but a plain summation of an example will be given later on that results in a final figure at an approximately reasonable temperature.

26 Where the regenerator has an efficiency F less than $F^{\text{max.}}$, as may be commercially desirable, it is evident that the work under the curve of expansion is less than for the exponent k, and greater than for n of maximum efficiency. Let us assume that this reduction of work is proportional to $\frac{F}{F^{\text{max.}}}$ times that occasioned by maximum efficiency, which may then be expressed by

$$\frac{F}{F^{\text{max.}}} \left\{ \frac{p_1 V_1}{k-1} \left[1 - \left(\frac{V_1}{V_2} \right)^{k-1} \right] - \frac{p_1 V_1}{n-1} \left[1 - \left(\frac{V_1}{V_2} \right)^{n-1} \right] \right\}$$

and having determined $F^{\text{max.}}$ and n (Equations 1 and 2), and p_1v_1, p_2v_2, p_c, and the value to be used for F, the efficiency may be expressed as

$$\text{Eff.} = \frac{\text{work under curve } k - \text{decrease of work} - \text{work under } P_c\,P_2}{\text{heat furnished by combustion}}$$

or

$$\text{Eff.} = \frac{\left\{ \begin{array}{l} \dfrac{p_1 V_1}{k-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \\ - \dfrac{F}{F^{\text{max.}}}\left\{ \dfrac{p_1 V_1}{k-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] - \dfrac{p_1 V_1}{n-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{n-1}\right]\right\} \\ - \dfrac{p_c V_1}{k-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \end{array} \right\}}{\left(1 - F\right)\left(\dfrac{p_1 V_1}{k-1} - \dfrac{p_c V_1}{k-1}\right)}$$

Dividing by $\dfrac{p_1 V_1}{k-1}$ we obtain

$$\text{Eff.} = \frac{\left\{ \begin{array}{l} \left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \\ - \dfrac{F}{F^{\text{max.}}}\left\{ \left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] - \dfrac{k-1}{n-1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{n-1}\right]\right\} \\ - \dfrac{p_c}{p_1}\left[1 - \left(\dfrac{V_1}{V_2}\right)^{k-1}\right] \end{array} \right\}}{\left(1 - F\right)\left(1 - \dfrac{p_c}{p_1}\right)} \quad \ldots(5)$$

an expression which, while it is formidable, can be used. We are now ready to figure theoretical efficiencies for any set of conditions and from them estimate the brake efficiencies, by using probable per cent of losses; that is, by departure from the theoretical cycle, by heat to water cooling and by the mechanical efficiency of the engine.

27 The reliability of this method is being checked by actual tests where they can be procured. For example, in Peabody's Thermodynamics, page 347, the theoretical efficiency of the Diesel cycle is given as 58%. We know by test that the water loss = 35% and the mechanical efficiency is 76%, hence, the brake efficiency = $58 \times (1\text{–}0.35) \times 0.76 = 28.6\%$. The actual efficiency by test = 28%.

We will allow for the regenerator engine a loss due to departure from the theoretical cycle of 10%, a water loss of 30%, a mechanical efficiency of 75%, giving a coefficient of 47½%, and for the regular cycle a departure from the cycle of 5%, a water loss of 35% and a mechanical efficiency of 80%, giving a coefficient of 48%.

Example: Let us take $p_1 = 400$ lb.; $p_c = 140$ lb.; $p_2 = 15$ lb.; all absolute. $k = 1.405$; $V_1 = 0.2$; $V_2 = 1$.

$$\text{From (2), } n = \frac{\text{Log } 400 - \text{Log } 15}{\text{Log } 1 - \text{Log } 0.2} = \frac{\text{Log } \frac{400}{15}}{\text{Log } 5} = 2.04$$

$$\text{From (1), } F^{\text{max.}} = \frac{1 - \frac{0.405}{1.04}(1 - 0.2)^{1.04} - \frac{15}{400} \times \frac{1}{2}}{1 - \frac{140}{400}} = 77\tfrac{1}{2}\ \%$$

Maximum efficiency = 100 %.
For other regenerator efficiencies

$$\text{Eff.} = \frac{0.311 - F\,(0.209)}{(1 - F) \times 0.65}$$

from which, remembering the coefficient mentioned above:

Regenerator Efficiency Per cent	With equal compressions of 140 lb. abs. the expression for efficiency is	Theoretical Efficiency Per cent	Coefficient Per cent	Brake Efficiency Per cent	B.t.u. per b.h.p.-hr.
77.5	Theoretical Maximum	100	47.5	47.5	5038
70	$0.311 - .70 \times .209 \div (1 - .7) \times 0.65$	85	47.5	40.4	6300
65	$0.311 - .65 \times .209 \div (1 - .65) \times 0.65$	77	47.5	36.6	7000
60	$0.311 - .60 \times .209 \div (1 - .6\ ) \times 0.65$	72	47.5	34.2	7450
55	$0.311 - .55 \times .209 \div (1 - .55) \times 0.65$	67	47.5	31.8	8000
50	$0.311 - .50 \times .209 \div (1 - .5) \times 0.65$	63.5	47.5	30.1	8500
0	Regular Gas Engine $= 1 - \left(\frac{V_1}{V_2}\right)^{0.405}$	47.9	48	23	11200

As a regenerator efficiency of 60% to 65% seems to be easily attainable, and 75% not impossible, it appears as if a heat consumption of 7000 B.t.u. could be obtained with commercial pressures.

28 Returning to the question as to whether a practical regenerator would cool the gases to the expected degree and realizing that in the cycles discussed instantaneous combustion presumably takes place,

while after-burning, that is, retarded combustion, is a necessary condition of practice, we will choose an example, showing the 60% regenerator with a compression of 140 lb. in which the same maximum temperature is delayed until $V_a = \frac{3}{10}$ whereby the highest pressure is reduced to about 285 lb. abs., if the heat added still equals $C_v(T_1 - T_c)$, from the efficiency given, the value of $C_v(T_3 - T_2)$ is obtained, T_3 being the absolute temperature of the exhaust. P_a and P_3 are likewise ascertained, and a new value of $n = 1.85$ results, and pressures corresponding to $V = \frac{4}{10}, \frac{6}{10}$ and $\frac{8}{10}$ are then derived. The card in Fig. 7, representing the approximate conditions of practice, is thus obtained.

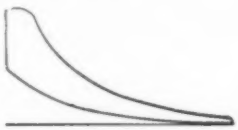


FIG. 7

GAS ENGINE CARD AS MODIFIED BY REGENERATOR

29 If a regenerator practically fulfills our conditions the final pressure P_3, derived from regenerator conditions, should not be higher than the value reduced from the theoretical efficiency.

30 It is probable that the temperature of the regenerator surfaces remains approximately constant throughout a cycle and that the returning gases issue at a constant temperature. This temperature is estimated as the peak temperature of the cycle, less the temperature withdrawn by the regenerator and that lost by work in the smaller cylinder before reaching the regenerator. Thus if $T_a = T_1$ = peak temperature = 2850° abs., $F(T_1 - T_c)$ = temperature regenerated = $\frac{6}{10}$ (2850 − 1000) = 1100°. $\frac{\text{Efficiency}}{2}$ $(T_1 - T_c)$ = temperature changed into work in the small cylinder, if made half by construction = $\frac{0.72}{2}$ (2850 − 1000) = 665°.

31 T_R = temperature of issuing gas = 2850 − (1110 + 665) = 1075°; allowing for gas burned in the regenerator and irregularities,

T_R will be taken at 1200° abs., P_c = 140 lb., P_1 = 285 lb., all absolute. Atmospheric temperature = 75° *F.* = 535° abs., T_a = 2390° *F.* = 2850° abs., P_a = 269 lb., regenerator = 60%, $V_1 = \frac{2}{10}$, $V_a = \frac{3}{10}$, $V_1 = 1$. From Eff. = 0.72 = $\frac{(T_1 - T_c) - (T_3 - T_2)}{T_1 - T_c}$, T_3 is obtained and p_3 = 29.5 lb. reduced, n = 1.85 (from Equation 2), and from T_R = 1200°, a regenerator condition, the value of p_3 is figured. Each particle of gas issues at T_R and at the pressure of the cycle, then it is considered as expanding freely with the exponent k from its volume V to V_2, that of release, when it will have an individual temperature $T_3 = T_R \left(\frac{V_1}{V_2}\right)^{k-1}$ from $T\,V^{k-1} = T_1\,V_1^{k-1}$ = a constant.

32 The effect of each particle on the final result is measured by its individual temperature and by its individual weight. This density or weight varies as the pressure of the cycle, which pressure varies as the exponent n. The value of each particle is thus taken to equal $T_3 \times p$. The summation of these effects averaged, gives the T_3, from which the P_3 desired is reduced.

	Pressures		V	T_3 deg. fahr.	$T_3 \times p$	
p_1	285.0 lb.		2/10	631	180,000	
p_2		160.0 lb.	4/10	831		135,000
p_d		75.0 lb.	6/10	977		73,200
p_e		44.5 lb.	8/10	1090		48,500
p_3	29.5 lb.		1	1200	35,500	
	2)314.5 =	157.3 lb.			2)215,500 =	108,000
		436.8 lb.				364,700

$T_3 = \frac{364{,}700}{436.8}$ = 835 deg. abs., or, P_3 = 23.4 lb. abs. = 8.4 lb. gage.

By the efficiency method of Par. 31, P_3 was 29.5 lb. abs. = 14.5 lb. gage.

33 Why this result should be lower than that given by the efficiency method is not apparent. Possibly too much work is charged to the small cylinder and possibly delayed combustion, by keeping up the average pressure of the cycle, increases the refrigerating effect of after-expansion. The object of the calculation, to show that the condition of a practical regenerator will allow the theoretical low exhaust pressures to be obtained, seems to be sustained.

34 The temperatures of the regenerator surface that follow from the above figures are 640 deg. fahr. *low* and 640 deg. + 1110 deg. = 1750 deg. fahr. *high*.

35 A discussion of the effects of such temperatures on materials available for construction is invited.

THE ENGINE

36 An engine to carry out this cycle (shown in Fig. 8 and Fig. 9) consists of two equal cylinders of uneven strokes. The cylinders are connected by a free passage through a regenerator, and are provided with valves on the heads. These valves are operated by a revolving cam, driven by spiral gears and a shaft centrally placed. The cam forms the casing of the governor, which may move a circular cam plate, varying only the closing of the fuel valve, all valves being opened by the fixed cam. A loose-fitting valve, shown in section at the cool end of the regenerator, may be used to close the passage between the cylinders at appropriate times and is exposed only to moderate temperatures. Fly wheels, crank shaft, housing and water cooling are provided. The regenerator casing is arranged so that it may be removed bodily, with the containing regenerator elements, by removing several bolts. All valves and casings are the same. There are no small rods, pins or cotters between valves and cam, and the cylinder heads may be removed without disturbing the valves or their connection, pipe connections, of course, being excepted. Provision is made for an igniter, if it be required, and an opening, closed by a peep tube, is left on the upper side of the regenerator, so that if open it may vent the burning gases used for preheating it. The piston in the small cylinder moves 90° to 100° ahead of that in the large cylinder. The cylinder with full stroke is called the large cylinder. The cylinder with short stroke is called the small cylinder.

37 In operation, the regenerator being heated, a charge of air is drawn into the large cylinder while a charge of gas is drawn into the small cylinder. The air is compressed in the large cylinder and the gas in the small cylinder. The gas is discharged mainly into the regenerator, its volume being varied by the control over the closing of the gas valve by the governor. During this time the passage between the cylinders may be closed. As the small piston advances ahead of the large one, its cylinder is filled with hot gas too rich to burn. The opening of the communicating passage admits com-

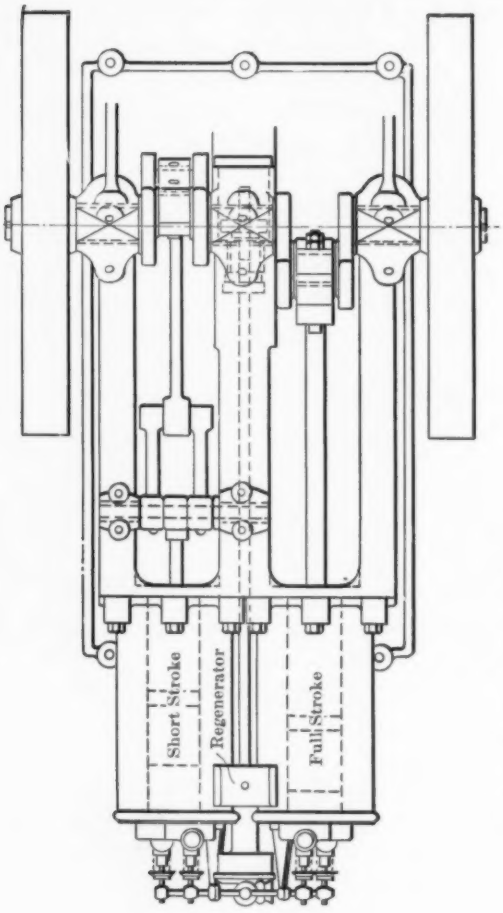
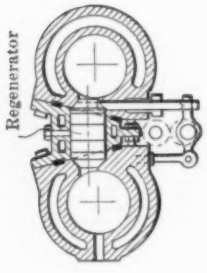


FIG. 8 PLAIN VIEW OF ENGINE



Section Through Cylinders and Regenerator

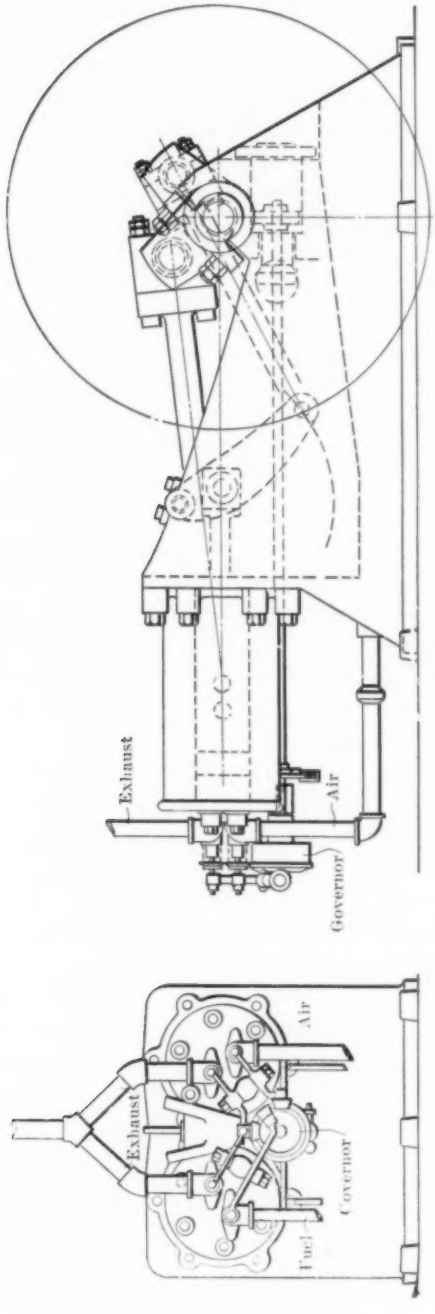


FIG 9 SIDE ELEVATION OF ENGINE

pressed air, through the regenerator, at a high temperature and mixes it with the hot gas at the point of highest compression of the entire charge. Ignition takes place, spontaneously or otherwise, causing combustion with increased pressure. A power stroke follows, in the small cylinder only, as the large piston poises at its dead center. As this latter advances it aspirates the highly heated gases back into the large cylinder where they are further expanded and exhaust follows, from both cylinders if desired. The engine is designed to give equal power in each cylinder and it is claimed to have the following advantages:

a As there is no clearance in either cylinder, complete scavenging is possible.

b As the air and gas are compressed separately, preignition cannot occur.

c Both the gas and air being highly heated before mingling, combustion is rapid at the moment when the proper conditions exist. No mixture is required, as the gas is at first too rich to burn; then heated air sprays into a heated atmosphere of gas; and when exact chemical proportions are formed ignition should be spontaneous. Afterwards, excess heated air flows in, and if unburnt fuel exists it is intermingled on its return through the regenerator in contact with hot surfaces. These are exactly the conditions of perfect combustion.

d It has been shown that delayed combustion is probably advantageous to the engine, keeping up the pressures and increasing the cooling effect on the exhaust during after-expansion.

e By delaying the combustion, the high peak pressures are avoided. High pressures are not required and only good, ordinary workmanship is called for.

f To withstand the temperatures practicable in the regenerator we have infusible materials such as are used in electric furnaces, and alloys of nickel now used in the arts. Hardness is immaterial, as the regenerator elements can be cast or moulded without finish.

g The practical limit of temperature being located, engines for rich, expensive fuel, such as illuminating gas, will have 50% increased economy for equal compression.

h While for weak fuels not now developing the limiting temperature, an equally high economy is available, with

increasing power, as the regenerator furnishes the heat units that the fuel lacks.

i Hydrocarbons are applicable by simple injection into the regenerator at the proper time.

j The low percentage of heat lost to water cooled surfaces, which is essential to this cycle seems, evidently, to be provided for in this design, as the high temperature gases are present only in the small cylinder, with its small amount of surface, while only a part of their weight remains throughout the stroke. In the large cylinder the temperatures are low, and the regenerator may be insulated. The design of this engine appears to be simple, and as the troubles due to imperfect mixtures and failure to ignite seem to be absent, regularity and certainty of operation should follow. Like the compound engine, the extra cylinder is the penalty paid for high economy.

38 Specific discussion of regenerators, their construction and effect, appears to be lacking in recent mechanical literature. Those who have a reasonable doubt that high-efficiency regenerator effect can be obtained in engine construction, may refer to an engine experiment made by Sir William Siemens[1] as far back as 1852, wherein the heat waste was one-twentieth; that is, the efficiency equalled 95%. Reference is also made to a test by Prof. Norton,[2] with a determination of heat waste equal to one-tenth, or an efficiency of regenerator equal to 90%.

[1]Rankine's Steam Engine, p. 345.
[2]Rankine's Steam Engine, p. 358.

GAS POWER SECTION

PRELIMINARY REPORT OF LITERATURE COMMITTEE (II)

ARTICLES IN PERIODICALS

AIR-COMPRESSORS, RATEAU CENTRIFUGAL, Frank Koester. *Engineering News, January 20, 1910.* 2½ pp., 7 figs., 3 curves. *bc.*

Of great interest in connection with the gas turbine problem.

AIRSHIP EXHIBITION, FRANKFURT A.M., INTERNATIONAL. *Zeitschrift der deutscher Ingenieure, March 5, 1910.* 3 pp., 7 figs. *bB.*

Description of several airship gas motors.

CAST-IRON UNDER HIGH TEMPERATURES, PERMANENT EXPANSION OF. *Power, January 11, 18, 25, 1910. cf.*

Several investigators have been prompted to search at this time, chiefly for superheated steam. Three papers were read before the Society in Boston; also tests by The Crane Company, May 1909.

COMBUSTION, CHEMICAL AIDS TO. *Power, February 15, 22, 1910.* ½p. *ac.*

Editorial reviewing catalytic theory of H. J. Williams. Also discussion of Mr. Williams' paper before the Society of Chemical Industry.

ELECTRICAL CONDUCTIVITY OF FLAMES CHARGED WITH METALLIC SALTS, M. U. Gouttefangeas. *Annales de Chimie et Physique, August 1909.* 11 pp., 1 fig., 4 tables. *c, scientific.*

Physical determination, with brief guide to the general subject.

ENGINE AND STARTING ENGINE, FOUR-CYLINDER OIL. *Engineering (London), January 28, 1910.* 2 pp., 11 figs. *bC.*

Made by Griffin Engineering Company, Bath, England; 70-h.p. crude oil engine with compressor and 5-h.p. engine for starting.

ENGINES AT BARROW STEEL WORKS, BLAST-FURNACE GAS. *Engineering (London), April 29, 1910.* 2 pp., 6 figs. *bB.*

Made by Richardsons, Westgarth & Co.

Opinions expressed are those of the reviewer, not of the Society. Articles are classified as: *a* comparative; *b* descriptive; *c* experimental; *d* historical; *e* mathematical; *f* practical. A rating is occasionally given by the reviewer, as *A, B, C.* The first installment was given in The Journal for May 1910.

ENGINE BUILT BY SULZER, DIESEL MARINE. *Die Gasmotorentechnik, February 1910.* 3 pp., 4 figs., 1 curve. *C.*

Description of 4-cylinder Diesel motor and account of results with a 150-h.p. motor.

ENGINES, CONSTRUCTIVE DETAILS OF DOUBLE-ACTING FOUR-CYCLE GAS, R. Drawe, Schleifmühle-Saarbrücken. *Zeitschrift der Verein deutscher Ingenieure, February 12, 19, 1910.* 10 pp., 34 figs. *bfA.*

Interesting account of improvement in design of cylinders, pistons, crossheads, valve gear, exhaust valve, water cooling and ignition of Ehrhardt and Scheuer gas engine.

ENGINE, DE LA VERGNE CRUDE OIL. *Engineering News, January 13, 1910.* 1½ pp., 3 figs., 1 table, 1 curve. *bc.* Also *Power, January 25.* 2 pp., 6 figs., 1 curve. *b.*

A compromise between Diesel and Hornsby-Akroyd. Operates upon a modified Diesel cycle, with lower pressures. Less than ½ lb. oil per b.h.p.-hr. Self-ignitive.

ENGINE, DEVELOPMENT OF THE KOERTING GAS, E. Koerting, Jr. *Zeitschrift der Verein deutscher Ingenieure, January 8, 1910.* 1 p. *bC.*

Lecture by E. Koerting, Jr., Hanover. Description of the Koerting 4-cycle engine of smaller sizes.

ENGINES FOR NAVIGATION, CRUDE OIL. *Die Gasmotorentechnik, November 1909.* 2 pp., 1 fig. *bB.*

Description of 120-h.p. gas motor built for Slomann & Co., Hamburg, by Germania Werft Stettin.

ENGINE, FOUR-CYLINDER HIGH-SPEED GAS. *The Engineer (London), April 29, 1910.* 1½ pp., 5 figs., 1 table. *bC.*

Made by Anderston Foundry Company of Glasgow and Middlesborough for direct connection to electric generators.

ENGINES, IGNITION IN GAS. *Annales des Mines de Belgique, Third Quarter, 1909.* Also *Annales des Travaux Publics de Belgique, 1909.*

Review of a French book by G. Yseboodt, engineer of the Belgian State Railways and director of l'Ecole Industrielle de Tubize. 8vo, 108 pp., 123 figs. A prize winner in 1903–1905.

ENGINE INDUSTRY DURING THE LAST FIVE YEARS, DEVELOPMENT OF THE GAS, E. Hubendick. *Gasmotorentechnik, December 1909.* 3½ pp., 2 tables. *deB.*

Account of a publication in "Bihang till Jernkontorets Annaler" of the number and capacity of large gas engines built.

ENGINE INSTALLATIONS IN EUROPE, NOTABLE GAS. *Engineering Magazine, February 1910.* 8 pp. *abdf.*

A series of halftone illustrations with descriptive captions.

ENGINE, MOTOR BOAT, Ernst Valentin, Berlin. *Die Gasmotorentechnik, December 1909.* 2 pp., 4 figs. *bB.*

Description of 4-cylinder and 8-cylinder motors built by Dürkopp & Co., Bielefeld.

ENGINE (MARINE), REVERSING CRUDE OIL. *Power, February 22, 1910.* 1 p., 2 figs. *b.*

Reversing gear described in detail.

ENGINE, TEST OF GAS, C. C. Winn. *Power, January 11, 1910.* 3 pp., 1 table, 8 curves, many indicator cards. *c.*

Speed is the basis to which the investigation relates. All results are stated in terms of varying speed. Tabular data are given. The curves drawn upon these data are badly forced and are quite deceptive.

ENGINE, THE COOPER GAS. *Power, January 11, 1910.* 2 pp., 4 figs. *bf.*

Double-acting, four-cycle engine, built by C. & G. Cooper, Mt. Vernon, O. Tandem cylinders.

ENGINE PISTON-RODS, LETTER ON WEAR OF GAS. N. Auchenbach. *Power, January 11, 1910. cf.*

Gives data as to cleansing gas of sulphur by use of oxide scrubber.

ENGINE, THE MODERN GAS, A. M. Levin. Review by Prof. L. S. Marks. *Engineering News, February 17, 1910.*

ENGINE, 2000-h.p. SINGLE-CYLINDER GAS. *Power, January 25, 1910.* 2 pp., 4 figs. *b.*

Koerting blowing engine, built by Siegen, Germany. 43½ in.–100½ in. x 55 in. tandem.

FUELS, GASOLENE AND ALCOHOL AS MOTOR, Robert M. Strong. *Engineering Magazine, January 1910.* 3 pp.

Abstract of Bulletin No. 392 issued by the United States Geological Survey, covering 200 comparative tests.

FURNACES, PRODUCER-GAS FIRED, Oskar Nagel. Review by Dr. C. E. Lucke. *Engineering News, February 17, 1910.*

INTERNAL-COMBUSTION ENGINE, DOUBLE-ACTING TWO-CYCLE. *The Engineer (London), February 18, 1910.* 3pp., 2 figs. *bcC.*

Made by Johnson's Motor Works, Harrogate. Differential pistons, no valves.

INTERNAL-COMBUSTION ENGINES, ELECTRIC IGNITION OF, John W. Warr. *Electrical Engineer (London), November 5, 1909.* 4½ pp., 8 figs. *bB.*

Paper presented before Institute of Electrical Engineers, Manchester Local Section, November 2, 1909.

INTERNAL-COMBUSTION MARINE ENGINES, Linton Hope. *Engineering (London), April 1, 1910.* 3¾ pp., 18 figs., 2 tables. *A.* Also *April 8,* b.h.p. table. ½ p. *B.*

Installation of Petrol Motors on Fishing Boats, with tables of dimensions of boats and motors.

LOW-TENSION IGNITION GEAR, GAS ENGINE. *Electrical Engineer (London), January 28, 1910.* 1½ pp., 5 figs. *bC.*

Description of Ignition Gear made by Felton & Guilleaume Lameyerwerke, A. G., Frankfort a. M.

MOTOR CAR FOR OREGON S.L.R.R., GASOLENE. *Engineering News, January 20, 1910.* 1 p. *b.*

200-h.p. car, designed by W. R. McKeen.

PLANT, LOG OF A RAILWAY GAS-POWER. *Power, April 12, 1910.* 2½ pp., 3 tables, 2 curves. *f, commercial.*

Two 800-h.p. units. The plant operates 24 hours per day, every day in the year.

PRODUCER AND ENGINE PLANT, TEST RUN OF, Wm. O. Webber. *Power, February 8, 1910.* 4 pp., 4 figs., 1 table, 3 curves. *bf.*

Thirty-day acceptance run at Soldiers' Home, Chelsea, Mass.

PRODUCER, A SIMPLE BITUMINOUS GAS. *Power, February 1, 1910.* 2 pp. *bf.*

100-h. p. auction producer; ran for six 24-hour days per week for two years, without repairs.

PRODUCER, BODY SUCTION GAS. *Indian and Eastern Engineer, November 1909.* 1 p., 1 fig. *bC.*

Description of producer made by Messrs. Robert Body, Ltd., Bury St., Edmunds, Suffolk, England.

PRODUCER, BITUMINOUS-FUEL SUCTION GAS. *Engineering News, March 31, 1910.* ½ p., 1 fig. *b.*

Reprint from Engineering Review (London). The Morton producer, Birmingham, England. Volatile matters fixed in the coked part of fire.

PRODUCER, CONTROL OF WATER FEED GAS, Frank P. Peterson. *Power, February 15, 1910.* 1 p. *f, general.*

Abstract of paper read before the National Gas and Gasolene Engine Trades Association.

PRODUCER-GAS PLANT, SMALL ISOLATED, Osborn Monnett. *Power, January 11, 1910.* 3 pp., 7 figs. *bf.*

Consists of two-wile suction producers, 100 and 115-h.p., rated capacity, and two Bruce-Macbeth 4-cylinder vertical engines. Anthracite pea coal.

PRODUCER-GAS POWER IN THE UNITED STATES, DEVELOPMENT OF, Prof. R. H. Fernald. *Power, March 1, 1910.* 1 p. *acf.*

Extracts from Bulletin No. 416 issued by the United States Geological Survey. Presents summarized results from tests of 75 coals, 6 lignites, 1 peat.

PRODUCER GAS, REMODELING GASOLINE ENGINES FOR, H. F. Smith. *International Marine Engineering, October 1909.* 2 pp. *bB.*

Paper before National Gas and Gasolene Engine Trades Association, June 1909. Points for design.

PRODUCER, TEST OF SUCTION GAS, Garland and Kratz. *Power, January 4, 1910.* 3 pp., 2 figs., 4 tables, 1 curve. *b.*

Reprint from Transactions. Concerns labor-saving methods of testing.

PRODUCER, THE HILL BITUMINOUS GAS. *Power, January 18, 1910.* 1 fig. *bf*

Combination of down-draft and up-draft principles.

PRODUCER, OIL-GAS, A. B. Davis. *Power, January 4, 1910.* 2 pp., 3 figs., 2 tables. *bcf.*

Abstract of paper before Ohio Society of Engineers. Good discussion of chemical reactions. Producer admits air to retorts, to prevent formation of tar. Heat efficiency: retorts, 89.8%; producer, 65.1%.

PUMP, HUMPHREY GAS. *Engineering Magazine, January 1910.* 2½ pp., 1 fig. Also *Engineering (London), February 11, 1910.* 1½ pp., 2 curves. *bce.*

Abstract of paper before the British Institution of Mechanical Engineers. Direct explosion pump applied to air compression. Describes action briefly and discusses forces acting, pressures produced and probable capacity and efficiency.

PUMPING WITH GASOLENE ENGINES. *Engineering Record, February 26, 1910.* ½ p., 1 table, 1 curve. *c.*

Abstract of governmental report of tests made in 1905 in California by J. N. LeConte and C. E. Tait

PUMPS, DIRECT-EXPLOSION. *Engineering Record, February 12, 1910.*

A letter from W. H. Smyth, dates and patent-numbers.

TURBINE (GAS-TURBINE) CONSTRUCTION, PRACTICAL STUDY IN OIL, Chas. Lemale. *La Technique Moderne, September 1909.* 5 pp., 5 figs., 6 curves. *bcfA.*

Full description of a most remarkable attempt at the internal-combustion prime-mover turbine built by the Baden Society for Combustion Turbo-Motors, after designs by Professor Rateau. The speed was 4000 r.p.m., the working pressure 70 lb., the compressor a 6-stage fan having a maximum efficiency of 70% and a capacity of 140,000 cu. ft. per hr. The curves characteristic of efficiency, etc., have been reproduced on too small a scale to be intelligible and the text line does not enlighten; but the photographs, expansion-curves, etc., are clear.

TURBINE, THE GAS, A. W. H. Griepe. *Power, March 8, 1910.* 3 pp., 6 figs., 1 table. *bcf.*

Discusses two suggested plans for turbine acted on directly by the exploded gases, one by Wegner and one by Griepe.

GENERAL NOTES

NATIONAL ASSOCIATION OF MANUFACTURERS

The National Association of Manufacturers held its fifteenth annual meeting, May 16–18, at the Waldorf-Astoria, New York. The proceedings covered questions of governmental policy, foreign relations, the tariff, patents, immigration, internal commerce, waterways, merchant marines, conservation of resources, etc., on which reports were made by committees. Attention was also given to industrial accidents and liability insurance. An illustrated lecture was delivered by Prof. F. R. Hutton, Honorary Secretary, Am. Soc. M. E., on The Prevention of Industrial Accidents. John Kirby, Jr., president, and F. H. Stillman, Mem. Am. Soc. M. E., treasurer, were re-elected.

NATIONAL ELECTRIC LIGHT ASSOCIATION

At the St. Louis convention of the National Electric Light Association, May 23–27, 1910, among the reports of standing committees, presented as part of the regular business, was that on Gas Engines, by I. E. Moultrop, Mem. Am. Soc. M. E., Chairman; and that on National Conservation, by Dudley Farrand, Mem. Am. Soc. M. E., Chairman.

Among the papers presented at the general and technical sessions were: A New Form of Tungsten Lamp, C. F. Scott; Water Intake from the Mississippi River for Two Electric Generating Stations in St. Louis, John Hunter, Mem. Am. Soc. M. E.,; Decentralized Steam Plants, R. D. DeWolf; Space Economy of Turbo-Generators, Paul M. Lincoln, Mem. Am. Soc. M. E.; Gas Engine Plants for Central Stations, Nisbet Latta, Mem. Am. Soc. M. E.; Feeder Regulators, E. E. Lehr; Direct-Current Turbo-Generators, W. L. Waters, Mem. Am. Soc. M. E.; Interesting Points in Modern Transformers, L. T. Robinson; The High-Efficiency Lamp, S. E. Doane. At the sessions of the new power transmission section, papers were given on The Public and the Water Powers, Henry L. Doherty, Mem. Am. Soc. M. E.; Present Problems of Water Transmission, Harold W. Buck; Modern Power-Transmission Systems, C. F. Scott; Electrical Phenomena of Transmission at High Voltages, C. P. Steinmetz, Mem. Am. Soc. M. E.

A special address was made on the evening of the association's twenty-fifth anniversary, by Past-President Samuel Insull, on Twenty-Five Years' Central Station Commercial Development.

AMERICAN WATER WORKS ASSOCIATION

The annual convention of the American Water Works Association was held at the Grunewald Hotel, New Orleans, La., April 26–30, 1910. Reports were

received at the opening sessions from committees on Publication, Electrolysis, Fire Protection, Water Works Standards, Depreciation, Reorganization in addition to the regular annual reports and accounts. Papers were presented on the Use of Electricity in Water Works Pumping, Charles B. Burdick; Legal Decisions, H. B. Rudisill; Methods of Handling Meters in Service, A. W. Cuddeback; The Conservation of Potable Waters, J. M. Diven; The Cost of Furnishing Water, Daniel W. Mead, Mem. Am. Soc. M. E.; A Coöperative Water Works Franchise, John W. Alvord; Municipal Ownership, Park Woodward; Baltimore County Ozonation Plant, A. E. Walden; The Danger of Contamination of Water Supply by Back Pressure from Fire Pumps, Alexander Milne; Suggestions as to Water Works for Fire Efficiency, W. H. Glore; Municipal Water Softening, Alexander Potter; Advertising the Water Works Business, D. R. Gwinn; The Settling Basins at Richmond, Va., E. E. Davis; The Fire Service Water Works of Winnipeg, H. N. Ruttan.

AMERICAN SOCIETY OF NAVAL ARCHITECTS

At the annual dinner of the American Society of Naval Architects, held at Rauscher's, Washington, D. C., May 7, 1910, addresses were made by the president, Engineer-in-Chief H. I. Cone, U. S. N.; the Secretary of the Navy; Hon. Joseph G. Cannon, Speaker of the House; Rear-Admiral Richard Wainwright; and L. P. Padgett and Ernest W. Roberts of the Congressional Committee in the Navy.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

The American Institute of Chemical Engineers held its semi-annual meeting June 22–24, 1910, at the Hotel Clifton, Niagara Falls, Canada. Papers were presented on the Corrosion of Iron and Steel and its Prevention, G. W. Thompson; Chemical Engineering Education, F. W. Frenchs; Manufacture and Industrial Applications of Ozone, Oscar Linder; Underground Waters for Manufacturing Purposes, W. M. Booth; Loss in Coal due to Storage, A. Bement, Mem. Am. Soc. M. E.; Plant Design, W. M. Grosvenor; and others.

THE INSTITUTION OF CIVIL ENGINEERS

A pamphlet has just been issued by the Institution of Civil Engineers, showing the architectural design of the institution's new building, to be erected at the corner of Great George and Princes Streets, on an area of 31,000 sq. ft. In style it is a modern rendering of the later Renaissance and pieces of timber and products brought from various parts of the British Empire, symbolic of the close relationship of the members of the institution, will be introduced into its construction. The plan of the building provides for council and committee rooms, reading rooms, and general offices on the ground floor, a lecture theatre, the great hall and the main library on the first floor, and on the second floor further library accomodations as well as writing and smoking rooms for the members. The basement and the third floor will be given up to provision for the general service of the premises.

The institution, which was established in 1818 and now numbers 9,136 members, is obliged to remove from its present headquarters because of the extension of the government offices. The erection of the new building affords an opportunity to meet and forestall in a comprehensive manner present and future needs in a building worthy of the prestige to which the society has attained.

INTERNATIONAL AMERICAN SCIENTIFIC CONGRESS

The International American Scientific Congress, which will hold its meeting for 1910 in Buenos Aires, Argentine Republic, July 10–25, will be divided into eleven sections; engineering; physics and mathematics; chemistry; geology; anthropology; biology; geography and history; economics and statistics; military science; naval science; psychology.

THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

A special meeting of the American Institute of Electrical Engineers, held in New York, May 27, 1910, was conducted by the Railway Committee of the Institute. Papers were read on the Electric Railway Catenary Trolley Construction by W. N. Smith, electric traction engineer with Westinghouse, Church, Kerr & Company; and The Application of Porcelain to Strain Insulators by Willard H. Kempton of the Ohio Brass Company of Mansfield, O.

The annual convention is now in session at the Waumbek Hotel, Jefferson, N. H.

AMERICAN INSTITUTE OF MINING ENGINEERS

A meeting of the American Institute of Mining Engineers will be held next fall in the Canal Zone, Panama, probably early in November. Besides the trip to and from the Isthmus it is proposed to include, among other possible stops en route, a visit to the mines and works of the Spanish-American Iron Company on the north shore of Cuba. Letters have been received from President Taft and from Colonel Goethals, the engineer in charge, which assure the institute of a cordial reception and a profitable as well as a delightful excursion.

NATIONAL MACHINE TOOLBUILDERS ASSOCIATION

The semi-annual convention of the National Machine Toolbuilders Association was held May 24 and 25 at Rochester, N. Y. F. A. Geier, Mem.Am.Soc. M.E., president of the association, called the meeting to order and congratulated the members on the progress made and the mutual good feeling engendered. Papers were read by Prof. F. B. Dyer, superintendent of the Cincinnati public schools, on the Work of the Cincinnati Continuation School, illustrated with stereopticon views; by Robert Pierpont, on the Future of the Automobile Business with Reference to Machine Tools; and by Wm. R. Wood, on a Court of Patent Appeals. R. K. LeBlond, Mem.Am.Soc.M.E., and Wm. Lodge, Mem.Am.Soc.M.E., discussed the relative merits of the cone drive and gear drive.

ILLUMINATING ENGINEERING COURSE AT JOHNS HOPKINS UNIVERSITY

Johns Hopkins University announces a course of thirty-six lectures on Illuminating Engineering, extending from October 26-November 8, 1910, arranged upon the initiative of the Illuminating Engineering Society, 29 West 39th Street, New York.

The lectures, which will be given under the joint auspices of the society and the university, will follow immediately the annual convention of the society to be held at the university, Monday, October 24, 1910. The course has three objects: (*a*) to indicate the proper coördination of those arts and sciences which constitute illuminating engineering; (*b*) to furnish a condensed outline of study suitable for elaboration into an undergraduate course for introduction into the curricula of undergraduate schools; (*c*) give practicing engineers an opportunity to obtain a conception of the science of illuminating engineering as a whole. The university will provide facilities for demonstrations at the lectures and will also have installed a working exhibit of apparatus for experimental work in light, illumination and illuminating engineering.

Among the lecturers announced are Edward P. Hyde, President Illuminating Engineering Society; Charles P. Steinmetz, Mem. Am.Soc. M.E., Professor of Electrical Engineering, Union University; Alexander C. Humphreys, Mem. Am.Soc.M.E., President Stevens Institute of Technology; A. G. Glasgow, London, England; L. B. Marks, New York; John W. Lieb, Jr., Mem.Am.Soc. M.E., New York; Walton Clark, Mem.Am.Soc.M.E., President Franklin Institute.

AMERICAN RAILWAY ASSOCIATION

At the annual meeting of the American Railway Association, held in the Engineering Societies Building, 29 West 39th Street, New York, on May 18, reports were received from committees on Maintenance, on Relations between Railroads, on Safe Transportation, on Explosives, and on Electrical Working. Delegates were appointed to the International Railway Congress and the following officers elected: president, Daniel Willard; vice-president, H. V. Mudge; members of the executive committee, C. R. Gray, I. G. Rawn.

WESTERN RAILWAY CLUB

The annual meeting of the Western Railway Club was held in the Auditorium Hotel, Chicago, on Monday, May 16. The following officers were elected for the year 1910–1911: J. F. DeVoy, president; C. B. Young, first vice-president; T. H. Goodnow, second vice-president; J. W. Taylor, secretary-treasurer; H. LaRue, G. H. Bryant, W. B. Hall, directors; D. L. Barnes, W. F. M. Goss, Mem. Am.Soc.M.E., C. A. Seley, F. W. Sargent, trustees.

An illustrated lecture on Early Railroading in Chicago was given by Frank L. Smith.

PERSONALS

Geo. O. Baker has severed his connection with the New England Engineering Co., with whom he has been associated as chief engineer, and has taken offices at 35 Wall St., as consulting and supervising engineer.

William O. Barnes, until recently assistant superintendent of the Miller Lock Co., Philadelphia, Pa., has accepted a position with the Iver Johnson Arms and Cycle Works, Fitchburg, Mass., as mechanical engineer.

Geo. H. Baush has resigned his position as general manager of the Fay Machine Tool Co., Philadelphia, Pa.

Grant D. Bradshaw, consulting engineer, Chicago, Ill., has become assistant steam engineer of the Cambria Steel Co., Johnstown, Pa.

Charles E. Bruff has severed his connection with the Power and Mining Machinery Co., New York, to look after the engineering work for the Chino Copper Co., Santa Rita, New Mexico.

John J. Chisholm, recently chief engineer of the Waterside station of the New York Edison Co., has become associated with the Westinghouse Electric Manufacturing Co., East Pittsburg, Pa.

A. C. Davis has resigned his position as master mechanic of the Pennsylvania Lines, Wellsville, O., and has purchased an interest in the American Manufacturing Concern, Jamestown, N. Y.

E. W. Dean has become connected with the Boston factory of the United Printing Machinery Co. He was formerly in the service of the Kidder Press Co., Dover, N. H.

Edward P. Decker recently factory manager of the Kemiweld Can Co., Detroit, Mich., has associated himself with Ernest M. Baker, under the firm name of E. P. Decker & Co., and will conduct a general engineering and construction business, with offices in Detroit, Mich.

Harry W. Henes has become associated with A. Bolter's Sons, Chicago, Ill.

Paul L. Joslyn, recently identified with the Minneapolis Steel and Machinery, Co., Minneapolis, Minn., has become associated with the Nordberg Manufacturing Co., Milwaukee, Wis.

Frederick Lane, formerly superintendent of Jenkins Brothers, Ltd., Montreal, Canada, now occupies a position with the Railway Signal Co. of Canada, Ltd., in the same capacity.

J. R. McColl, of the engineering department of the American Blower Co., Detroit, Mich., has severed his connection with that company in order to become a member of the new firm of Ammerman, McColl & Anderson, Detroit, Mich., which will conduct a consulting engineers practice.

Harold T. Moore, formerly production engineer of the Bridgeport Brass Co., Bridgeport, Conn., has become identified with the Cruse-Kemper Co., Ambler, Pa.

Charles L. Newcomb, Jr., is now connected with the engineering department of the Denver Rock Drill & Machinery Co., Denver, Colo. Until recently Mr. Newcomb was with the International Steam Pump Co., with whom the Denver Co. is very closely associated.

Robert B. Owens, recently on the engineering staff of the Southern Power Co., Charlotte, N. C., has been appointed secretary of the Franklin Institute, Philadelphia, Pa.

James Posey, recently associated with Henry Adams, Baltimore, Md., as assistant engineer, has become consulting engineer of the firm, Painter & Posey, of the same city.

N. S. Reeder, formerly identified with the Canada Car Co., Ltd., Montreal, Canada, in the capacity of general manager, has become associated with the Western Steel Car and Foundry Co., Chicago, Ill.

Arthur L. Robinson has been appointed superintendent of the mechanical division of the Panama canal by Geo. W. Goethals, and as such will have charge of all the machine shops in the canal zone, where the tools used in the work are built and repaired.

A. L. Saltzman, formerly in charge of the drafting department of Walter Scott & Co., Plainfield, N. J., has become identified with the Edison Company's Laboratory, Orange, N. J.

P. S. Steenstrup, formerly manager of the Hyatt Roller Bearing Co., Harrison, N. J., has been appointed manager of the new branch of the Columbia Motor Car Co., at Seattle, Wash.

Robert L. Streeter has been appointed assistant professor of mehanical engineering, Rensselaer Polytechnic Institute, Troy, N. Y. He was formerly instructor of machine design of the Buffalo Technical High School, Buffalo, N. Y.

Ambrose Swasey has received the degree of Doctor of Science from Dennison University, Dayton, O.

Leroy Tabor has resigned his position as superintendent of the Tabor Manufacturing Co., Philadelphia, Pa., to accept a position with the Morrow Manufacturing Co., Elmira, N. Y.

Howard E. Troutman has become associated with the International Steam Pump Co., as assistant sales manager of the Chicago, Ill., office.

Merton G. White, formerly manager of sales department of A. D. Granger Co., New York, has been appointed manager of the New York office of the Fitchburg Steam Engine Co.

H. L. Whittemore, associate professor in theoretical and applied mechanics, University of Illinois, Urbana, Ill., has received the appointment of engineer of tests in the Ordnance Department of the U. S. Government at Watertown Arsenal, Watertown, Mass.

Fred M. Whyte, who has been chief mechanical engineer of the New York Central Lines, has been appointed general manager of the New York Air Brake Co., with headquarters at Watertown, N. Y.

C. T. Wilkinson, of the power and mining machinery department of the General Electric Co., Schenectady, N. Y., has left this country for a visit of several months to England and France for the purpose of investigating the high-tension transmission situation.

E. E. Wood, until recently president and manager of the Walcott & Wood Machine Tool Co., Jackson, Mich., will be factory manager of the new Grant & Wood Manufacturing Co.

CURRENT BOOKS

PRINCIPLES AND PRACTICE OF IRONFOUNDING. By E. L. Rhead. *Manchester England, Scientific Pub. Co., 1910.* Cloth, 8vo, 505 pp. Price, 7s., 6d.

Contents: Iron and Steel in the Foundry; Testing Cast Iron; Moulding Materials in the Foundry; Sand-Mixing Appliances in the Foundry; Foundry Blackings and Partings; Moulding Tools and Appliances; Moulding Operations; Cores and Core Making; Loam Moulding; Plate and Machine Moulding; Chill Castings; Malleable Castings; Melting Iron for Foundry Purposes; Blast for Cupolas; Air Furnaces; Appendix.

THE REINFORCED CONCRETE POCKET BOOK. By L. G. Mensch. *San Francisco, Cal., Neal Pub. Co., 1909.* Morocco, pocket size, 216 pp. Price, $10.

Contents: Useful Tables, Rules and Illustrations for the Convenient Design, Rational construction and Ready Computation of Cost of Reinforced Concrete Girdles, Slabs, Footings, Columns, Buildings, Retaining Walls, Tanks, Grain Elevators, Coal Bins, Water Pipes, Sewers, Dams, Bridges, Smoke Stacks, Piles, etc.

ANNUAL REPORT OF THE WATER SUPPLY COMMISSION OF PENNSYLVANIA, 1908. *Harrisburg, C. E. Aughinbaugh, 1910.* Cloth, 8vo, 109 pp., illustrated.

Contents: Inactive Water Companies; Obstructions to Streams, Methods of Bank Protection; Rainfall; Droughts, the Drought of 1908; Floods during 1908; Report of the Engineer of the Commission upon the Causes and Methods of Relief from Floods in Turtle Creek, Westmoreland and Allegheny Counties.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Year Book, 1910. *New York, 1910.*

ANNUAL LIBRARY INDEX, 1909. *New York, 1910.*

BAYLOR UNIVERSITY. Home-Coming of Baylor University. (Bulletin No. 1, Vol. 13.) *Waco, 1910.*

BOILER TROUBLES AND THEIR TREATMENT. By G. W. Wood. *Philadelphia, 1910.* Gift of author.

FOREST NURSERY AND REFORESTATION WORK IN MASSACHUSETTS. By R. S. Langdell. *Boston, 1910.* Gift of Massachusetts State Forester.

KÖNIGLICHE TECHNISCHE HOCHSCHULE ZU MÜNCHEN. Bericht uber das Studienjahr, 1908–1909. *Munich, 1910.*

———Program 1909-1910. March 1910. *Munich, 1910.*

MARYLAND CONSERVATION COMMISSION. Report 1908-1909. *Baltimore, 1909.* Gift of the Commission.

MASCHINEN-ELEMENTE. Vol. 1–2. By C. Bach. *Leipzig, 1908.*

MASSACHUSETTS STATE FORESTER. 6th annual report. *Boston, 1910.* Gift of Massachusetts State Forester.

McGILL UNIVERSITY. Bulletin, *January 1910. Montreal, 1910.*

MUNICIPAL FRANCHISES. Vol. 1. By D. E. Wilcox. *Rochester, 1910.*

NEW YORK CITY BOARD OF CITY MAGISTRATES. Annual Report, 1909. *New York, 1910.* Gift of the board.

PRINCIPLES AND PRACTICE OF IRON FOUNDING. By E. L. Rhead. *Manchester, England, Scientific Pub. Co., 1910.*

SCHWEIZERISCHE BAUZEITUNG. Vol. 55-date. *Zurich, 1910-date.*

SMOKE PREVENTION IN STEAM BOILER PLANTS. By H. D. Frary. (Reprinted from Minnesota Engineer, March 1910.) Gift of author.

STORY OF A TARIFF: THE TARIFF ACT OF 1909. Gift of J. H. Gallinger.

TECHNICAL LEAGUE. Bulletin. Vol. 1–2, No. 4. August 1909–April 1910. *New York, 1909–1910.* Gift of the league.

TROISIEME CONGRÈS INTERNATIONAL AERONAUTIQUE, Milan, 22–28 Octobre, 1906. Rapports et Memoires. *Paris, 1907.*

EXCHANGES

EXPERIMENT STATION RECORD. Vol. 20–21. *Washington, 1908–1909.*

UNITED STATES NAVY DEPARTMENT. Message of the President, 1863. *Washington, 1863.*

———Report of the Secretary. 1862, 1866, 1868, 1871, 1874, 1875, 1877, 1879, 1881, 1882, Vol. 1–2, 1883, Vol. 1–2, 1884, Vol. 1–2, 1886, 1888, 1889, pts. 1–2, 1890–1897, 1898, Vol. 1–2, 1900, 1902–1908. *Washington, 1862–1908.*

———Report of Board on Comparative Trials of the Scout Cruisers, Birmingham, Salem, Chester, December 22, 1909. *Washington, 1910.*

WESTERN SOCIETY OF ENGINEERS. Year Book, 1910. *Chicago, 1910.*

TRADE CATALOGUES

ACME MACHINE CO., *Cleveland, O.* Bolt, nut and forging machinery, 162 pp.

BARDONS & OLIVER, *Cleveland, O.* Turret lathes and machinery, 302 pp.

BLAKE & KNOWLES STEAM PUMP WORKS, *New York, N. Y.* Bulletin B-K, 843, Open feed heater, 12 pp.

BUTTERFIELD & CO., *Derby Line, Vt.* Taps, stocks and dies, screw plates, reamers, tools for steam fitters, etc., 90 pp.

HANNOVERSCHE MASCHINENBAU-ACTIEN-GESELLSCHAFT, *Hannover-Linden.* 4-cylinder balanced compound locomotives, 26 pp.

INDUSTRIAL INSTRUMENT CO., *Foxboro, Mass.* Foxboro Recorder, March 1910, 31 pp.

KENNEDY VALVE MFG. CO., *Elmira, N. Y.* Valves for water-works, 30 pp.

J. GEO. LEYNER ENG. WKS. CO., *Littletown, Colo.* Bulletin 1016, Drilling costs, 4 pp.

NEWTON MACHINE TOOL WORKS, Philadelphia, Pa. Catalogue 46, Bolt threading machines and multiple automatic die heads, 15 pp.

OHIO BRASS CO., *Mansfield, O.* Bulletin, April 1910, 24 pp.

UNITED ENGINEERING SOCIETY

A. L. A. PORTRAIT INDEX, 1906. *Washington, 1906.*

ELECTRIC POWER PLANTS. By T. E. Murray. *New York, 1910.* Gift of author.

ENGINEERING INDEX, 1909. *New York, 1910.*

IOWA BOARD OF RAILROAD COMMISSIONERS. 27th–31st annual reports, 1904–1908. *Des Moines, 1905–1909.* Gift of commissioners.

JOURNAL OF GAS LIGHTING, WATER SUPPLY AND SANITARY IMPROVEMENT. Vol 23–50, 51 (except January 3, May 8, June 26 and index); 52 (except July 17, 24, 31 and index); 53-56 (except indexes); 58 (except index); 59 (except all of January, February 2 and 16, all of March, April 12, May 3 and 31 and index); 60 (except October 11, November 1 and index); 61 (except June 13, 20, 27 and index); 64–79; 80 (except October 14); 81 (except March 24); 82; 83 (except September 1); 84 (except October 27; 85–87, 89, 90 (except index); 91 (except July 11–August 8, August 22, December 12); 93 (except January 30, February 6); 94–95; 96 (except November 6); 97–98 (except indexes); 100, No. 2326. *London, 1874–1907.* Gift of American Gas Institute.

NEBRASKA STATE RAILWAY COMMISSION. 1st and 2d annual report. *Lincoln, 1908, 1909.* Gift of the commission.

NEW HAMPSHIRE RAILROAD COMMISSION. 65th annual report, 1909. *Manchester, 1910.* Gift of commissioners.

NEW PRONOUNCING DICTIONARY OF SPANISH AND ENGLISH LANGUAGE. By M. Velasquez de la Cadena. *New York, 1909.*

OHIO RAILROAD COMMISSION. 1st and 3d reports. *Springfield, 1906, 1908.*
Gift of the commission.
POOLE'S INDEX TO PERIODICAL LITERATURE. Vol. 6, 1902–1906. *Boston, 1908.*

TRADE CATALOGUES

SCHNEIDER & CO., *Paris.* Products and machinery, 19 pp.
———CREUSOT AND MANGANESE STEEL USED IN RAILWAY CONSTRUCTION, 9 pp.
———AUTOMOBILE WHEELS, 9 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

032 Assistant draftsman for cement mill repair and reconstruction; salary from $50 to $100 per month, according to usefulness. Apply with full particulars direct to Texas Portland Cement Company, Dallas, Texas, Jno. B. Mayo, Chief Draftsman.

033 An electrical engineer, established in his own wiring contracting business two years, wants young man capable of estimating wiring costs from plans, to invest $5000 in corporation to be formed to take over this business; must take active part, principally in the estimating and commercial part of the work. Acquaintance with architects and engineers desirable.

034 Draftsmen for mill-wright work and building plans; prefer young men not over 25 years of age, with tool-room experience or techincal education; two or three years' drafting work. Start at $20 to $25 per week; can give varied experience in laying out new models with the tools for manufacturing and designing special machinery from light automatic machines to heavy hydraulic work. Location, New Jersey.

035 Electrical or mechanical technical graduate of about four years' experience, as inspector and engineer on maintenance and operating. Salary to start, $22.50 per week. Location, New York.

036 Man of good mechanical knowledge wanted, technical graduate preferred, to take charge of price setting in one of the largest machine shops in the eastern states. Excellent opportunity for the right man.

037 Instructor in mechanical and architectural drawing, Tuesday and Thursday evenings, October to May. Drafting room practice and some experience in teaching necessary. Location one hour from Manhattan.

038 Man thoroughly acquainted with modern machine tools and machine shop practice for position in works office of factory; salary and responsibilities depend upon ability. Would probably be called first to look over the machine and tool equipment, determine whether they were the best obtainable for the work to be performed, whether saving could be effected by discarding some of present machines and purchasing others, and determine best methods of handling work in the shop.

MEN AVAILABLE

77 Technical graduate experienced in the design and construction of power plants, industrial plants and mill buildings, wants position which will not confine him to drafting board or office, while not objecting to some office work or drawing.

78 Eastern member, nearly 25 years' experience as civil and mechanical engineer in designing, construction, selling, installation and operating departments of modern power equipment and manufacturing plants; wide personal acquaintance United States, Canada, Great Britain and the continent; successful in dealing with U. S. and foreign government engineer departments, municipal and other public works; familiar with modern office, shop organization and costs; drafting specifications and contracts; good correspondent and executive; active, energetic and resourceful. At present engaged but open for consideration of still larger activities.

79 Superintendent and engineer desires engagement, 18 years' experience designing, estimating and selling special machinery, shop management, systematizing. At present shop manager of large concern; member A. S. M. E.

80 Associate 18 years experience in designing and building automatic machinery, established system for this class of work; 39 years of age. Desires position as superintendent or assistant manager. At present employed.

81 Experienced sales manager or representative desires engagement; preferably with manufacturer of water-tube boiler or other power plant apparatus. Age 32. Extensive experience in designing and selling. Widely acquainted. Location in East or South preferred. Exceptional references.

82 Member wants position as general superintendent or works manager; age 35; practical mechanic, technical education, good hustler and organizer, with experience including heaviest class of machinery.

83 Member, technical graduate with 13 years successful experience as designer, engineer of tests, mechanical engineer in charge and superintendent of engine works, would consider position with either firm of consulting engineers or instructor in machine design and construction. Highly recommended. At present employed.

84 Member, desires position as mechanical engineer for large manufacturing company; about 25 years experience in general mechanical engineering. Salary, $4500 per year. First class reference.

85 Energetic engineer, technical school graduate; 20 years practical experience in the engineering of large up-to-date industry; automatic machine design and construction; building, and power plant design and construction; all complicated engineering problems involved in textile work; operation of large machine shop engaged in building special machinery; mill and power plant maintenance and operation; process investigation and improvement. Works manager or supervising engineer. Best of references.

86 M. E., Stanford University, experienced as instructor in mechanical engineering; also machinist and draftsman. Considerable experience in teaching private classes in descriptive geometry, algebra, trigonometry, calculus and other similar subjects. At present instructor in mechanical engineering connected with experimental engineering laboratory. Desires similar position.

87 Graduate M. E., post graduate work in electrical engineering, class 1897, five years experience in shop and drafting room, eight years testing engineer, mechanical engineer and superintendent. Familiar with marine and power plant machinery and equipment. Inventive and executive ability; organization and shop efficiency. Desires position as superintendent, assistant superintendent, ássistant works manager or assistant to consulting engineer; location immaterial.

88 Junior member, graduate of prominent engineering school of middle west, desires responsible position in charge of work or with consulting engineer. Four years experience in charge of college engineering laboratory, including strength of materials; four years drafting and designing with companies building well known line of steam engines. Salary $2000 per year.

89 Graduate in mechanical engineering B. S. and M. E. Experience cover both mechanical and civil fields, general shop practice, railroad location· general engineering and contracting, including power plant design, construction and operation, sewers, waterworks. etc. Desires responsible position with manufacturing or engineering and contracting concern.

90. Technical graduate, eighteen years experience, power producing machinery, boilers, engines, pumps, air and gas compressors and power plant auxiliaries; application of steam, gas, electric and hydraulic power to machinery, familiar with machinery for mining, quarry and tunnel work; responsible positions in the production, engineering and sales departments. At liberty about July 1st. Would prefer company where permanency and advancement are possible. Eastern location preferred.

91 Junior member, executive ability, desires responsible charge of engineering work in New York or vicinity of Orange, N. J. Technical education, chief draftsman four years, shop foreman one year. Age 32. Salary $1500.

92 Member, over twenty years experience, design, superintendence and management in shop and field, desires position, preferably near Philadelphia.

93 Associate, graduate mechanical engineer, fourteen years experience in general engineering work, machine shop, testing power plant design, construction and operation. Five years electric railway work, involving civil, mechanical and electrical engineering; good executive ability, experience in office methods, correspondence, etc. Wishes executive position involving responsibility. Salary $2500.

94 Junior, technical graduate, at present engineer of brass mill; experience laying out and building new plants; construction and design brass and copper mill machinery, furnaces etc; design and operation steam, high pressure hydraulic and electric power plants; desires to change to position as mechanical engineer of manufacturing plant.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

AFFLECK, H. Watson (Associate, 1906), Pres., Keystone Engrg. Co., 719–721 Noble St., and *for mail*, 1707 Cayuga St., Philadelphia, Pa.

ALLEN, John Robins (1894; 1903), Cons. Engr. and Dir. Dept. of Engrg. Robert College, Constantinople, Turkey.

ANDERSON, Emanuel (Associate, 1907), 5692 Ridge Ave., Chicago, Ill.

APPLETON, Thomas (1893), Supt. of Constr., U. S. Pub. Bldgs., East St. Louis, Ill.

BAEHR, William Alfred (1903), Cons. Engr., Peoples Gas Bldg., Chicago, Ill.

BAKER, George Otis (1906), Cons. and Supervising Engr., 35 Wall St., and *for mail*, 570 W. 183d St., New York, N. Y.

BAKER, William E. (1902), W. E. Baker & Co., 105 W. 40th St., New York, N. Y.

BARNES, William O. (1908), Mech. Engr., Iver Johnson Arms & Cycle Wks., and *for mail*, 110 Blossom St., Fitchburg, Mass.

BAUSH, George Henry (1905), 480 Northampton St., Holyoke, Mass.

BEECHER, J. F. (Associate, 1908), Checker, M.E.Dept., Pa. Steel Co., and *for mail*, 326 North St., Harrisburg, Pa.

BERLINER, Richard W. (Junior, 1903), V. J. Hedden & Sons Co., Bldrs., Metropolitan Life Tower, and *for mail*, 608 Riverside Drive, New York, N. Y.

BITTERLICH, Walter J. (Junior, 1906), Ch. Draftsman, Hood Rubber Co., and *for mail*, 9 Irving St., Watertown, Mass.

BIXBY, Col. William H. (1888), Life Member; U. S. Engr., 508 Colorado Bldg., Washington, D. C.

BORNHOLT, Oscar Charles (1904; 1909), John R. Keim Mills, Buffalo, N. Y.

BRADSHAW, Grant D. (Junior, 1904), Asst. Steam Engr., Cambria Steel Co., Johnstown, Pa.

BRENNER, Wm. H. (1897), Managing Dir., Zemma Wks., Ltd., Isogo Mura, Yokohama, Japan, and Mgr., British Columbia Mfg. Co., Ltd., P. O. Box 154, New Westminster, B. C., Canada.

BROOKS, Louis C. (Junior, 1901), 167 Furman St., Schenectady, N. Y.

BRUFF, Charles E. (1908), Chino Copper Co., Santa Rita, N. Mexico.

BUKER, Henry (1907), Western Rep., Brown & Sharpe Mfg. Co., 626–630 Washhington Blvd., Chicago, Ill.

BURGESS, Edward W. (Junior, 1908), J. I. Case Threshing Mch. Co., and *for mail*, 1216 Main St., Racine, Wis.

CHISHOLM, John James (Associate, 1904), Supt. of Power, Westinghouse Electric & Mfg. Co., East Pittsburg, Pa.

CHRISTENSEN, Chas. C. (1890), Estimating Engr., Allis-Chalmers Co., and *for mail*, 2910 Logan Blvd., Chicago, Ill.

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FERRY, Charles H., May 2, 1910
FOSTER, Charles F., May 8, 1910
KERR, Walter C., May 8, 1910
McKAY, John Edwards, May 12, 1910
SAVERY, Thomas H., April 5, 1910

GAS POWER SECTION

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MILLER, Frank Louis (1910), Mem. Am. Soc. M. E.
RANDALL, Dwight T. (1910), Mem. Am. Soc. M. E.
THOMAS, Fred H. (1910), Mem. Am. Soc. M. E.

STUDENT BRANCHES

CHANGES OF ADDRESS

ALLEN, Chas. C. (Student, 1909), 1727 Church St., Galveston, Tex.
BADEAU, Ralph P. (Student, 1909), 416 Linden Ave., Elizabeth, N. J.
BAUGHMAN, I. N. (Student, 1909), Box 827, Marseilles, Ill.
BESS, Earl (Student, 1910), Bess Laundry Mchy. Co., Hamilton, O.
CARNAHAN, O. A. (Student, 1909), Bolivar, N. Y.
CHU, P. F. (Student, 1909), 319 Dryden Rd., Ithaca, N. Y.
COLEMAN, Wm. F. (Student, 1909), 4300 Park Ave., Champaign, Ill.
COOK, G. C. (Student, 1909), Millington, N. J.
COYLE, J. F. (Student, 1909), Matheson Motor Car Co., Wilkes-Barre, Pa.
DUNSHEATH, L. M. (Student, 1909), 127 Galena Blvd., Aurora, Ill.
GRENOBLE, H. S. (Student, 1909), 1380 Summit St., Columbus, O.
GROSSBERG, Arthur S. (Student, 1909), 407 E. Tenth St., Topeka, Kan.
HATMAN, Julius G. (Student, 1910), 749 Van Buren St., Milwaukee, Wis.
HEILMAN, H. C. (Student, 1909), 1511 N. 20th St., Philadelphia, Pa.
LAWRENCE, J. H. (Student, 1909), 128 W. 91st St., New York, N. Y.
LAY, Robert P. (Student, 1910), 203 Barrett St., Syracuse, N. Y.
LORD, J. Willard (Student, 1910), R. F. D. 43, Norwalk, Conn.
MERRIAM, Frank E. (Student, 1910), 80 Madison St., Skowhegan, Mo.
MESTON, A. F. (Student, 1909), 816 Ross Ave., Wilkinsburg, Pa.
QUICK, Ray Lewis (Student, 1909), 141 Washington St., Hartford, Conn.
SIMONTON, P. D. (Student, 1910), R. F. D., Yarmouth, Me.
STROUSE, A. F. (Student, 1910), 1317 Dennison Ave., Pittsburg, Pa.
VAUGHAN, L. L. (Student, 1910), Franklin, Va.
WATROUS, R. W. (Student, 1910), 559 Ashland Ave., St. Paul, Minn.
WHITE, J. Frank (Student, 1910), Huntingdon, Pa.
WOOD, S. G. (Student, 1909), Box 145, Franklin Park, Ill.

NEW MEMBERS

CORNELL UNIVERSITY

FARRINGTON, T. H. (Student, 1910), 777 Stewart Ave., Ithaca, N. Y.
FRIED, J. A. (Student, 1910), 105 Highland Pl., Ithaca, N. Y.
SOUTHWICK, Charles (Student, 1910), 222 University Ave., Ithaca, N. Y.
THOMAS, F. (Student, 1910), Sheldon Court, Ithaca, N. Y.
WINSHIP, R. (Student, 1910), 458 Cascadilla Pl., Ithaca, N. Y.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

COPELAND, S. B. (Student, 1910), 234 Newbury St., Boston, Mass.
MacPHERSON, R. G. (Student, 1910), 30 Pine St., South Framingham, Mass.

STEVENS INSTITUTE OF TECHNOLOGY

CUTTER, J. D. (Student, 1910), 1208 Pacific St., Brooklyn, N. Y.
SCHLEGEL, C. A. (Student, 1910), 507 River St., Hoboken, N. J.

UNIVERSITY OF ARKANSAS

BOLES, C. B. (Student, 1910), 216 N. E. St., Fayetteville, Ark.
DICKENSON, B. F. (Student, 1910), 1608 Battery St., Little Rock, Ark.

UNIVERSITY OF ILLINOIS

COBB, C. C. (Student, 1910), 909 W. Green St., Urbana, Ill.
HOMS, J. M. (Student, 1910), 1012 W. Oregon St., Urbana, Ill.

UNIVERSITY OF MAINE

CHAPMAN, G. B. (Student, 1910), Phi Eta Kappa House, Orono, Me.
PINKHAM, C. J. (Student, 1910), Oak Hall, Orono, Me.

UNIVERSITY OF NEBRASKA

STRIETER, M. E. (Student, 1910), 104 Oneida Ave., Davenport, Ia.
WOHLENBERG, W. J. (Student, 1910), 844 Seventh St., Lincoln, Neb.

UNIVERSITY OF WISCONSIN

SCHLECK, Walter H. (Student, 1910), Box 530, South Milwaukee, Wis.

COMING MEETINGS

JULY–AUGUST

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN EXPOSITION IN BERLIN

June 1–Aug. 31. American Manager, Max Vieweger, 50 Church St., New York.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

June 30–July 1, semi-annual meeting, St. Louis, Mo. Secy., W. M. Mackay, P. O. Box 1818, New York.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

July 26–29, meeting with Institution of Mechanical Engineers, in Birmingham and London, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SOCIETY FOR TESTING MATERIALS

June 28–July 2, annual meeting, Atlantic City, N. J. Papers: Untruly and Unevenly Chilled Car Wheels, D. T. West, Mem.Am.Soc.M.E.; Aluminates: Their Properties and Possibilities in Cement Manufacture, Henry S. Spackman, Mem.Am.Soc.M.E.; Fuel Investigation, U. S. Geological Survey, Progress during the year ending June 30, 1910, J. A. Holmes, Mem.Am.Soc.M.E. Secy., Edgar Marburg, University of Pennsylvania, Philadelphia.

CANADIAN ELECTRICAL ASSOCIATION

July 6–8, annual convention, Royal Muskoka, Lake Rosseau. Secy., T. S. Young, Confederation Life Bldg., Toronto, Ont.

INTERNATIONAL ACETYLENE ASSOCIATION

August 3–5, annual meeting, Congress Hotel Annex, Chicago, Ill. Secy., A. Cressy Morrison, 157 Michigan Ave.

INTERNATIONAL EXPOSITION OF CLAY, CEMENT AND LIME INDUSTRIES

June 1–July 18, second annual convention, Berlin. Under the auspices of German Association for the Clay, Cement and Lime Industries, Dreyse-Str. 4, Berlin, Germany.

INTERNATIONAL RAILWAY CONGRESS

July 4-16, Berne, Switzerland. Executive Committee, rue de Louvain, 11, Brussels.

INTERNATIONAL RAILROAD BLACKSMITHS ASSOCIATION

August 17-19, annual convention, Detroit, Mich. Secy., A. L. Woodworth, Lima, O.

NATIONAL ASSOCIATION OF MASTER SHEET METAL WORKERS
August 10–13, Lulu Temple, Broad and Spring Garden Sts., Philadelphia, Pa. Secy., Otto Goebel, 523 Columbus Ave., Syracuse, N. Y.

NATIONAL ELECTRIC CONTRACTORS ASSOCIATION
July 20, annual meeting, Atlantic City, N. J. Secy., W. H. Morton, Martin Bldg., Utica, N. Y.

OHIO ELECTRIC LIGHT ASSOCIATION
July 26–28, annual convention, Cedar Point, O. Secy., P. L. Gaskill, Greenville, O.

TRAVELING ENGINEERS ASSOCIATION
August 16–19, annual convention, Clifton Hotel, Niagara Falls, Canada. Secy., W. O. Thompson, care of N. Y. C. Car Shops, East Buffalo, N. Y.

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GEORGE WESTINGHOUSE.....Pittsburg, Pa.

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Terms expire at Annual Meeting of 1910

CHARLES WHITING BAKER.....New York
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Terms expire at Annual Meeting of 1911

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Members of the Council for 1910

JOHN R. FREEMAN.....Providence, R. I.
FREDERICK W. TAYLOR.....Philadelphia, Pa.
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M. L. HOLMAN.....St. Louis, Mo.
JESSE M. SMITH.....New York

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HENRY G. STOTT.....New York

Terms expire at Annual Meeting of 1910

H. L. GANTT.....New York
I. E. MOULTROP.....Boston, Mass.
W. J. SANDO.....Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. SELLERS BANCROFT.....Philadelphia, Pa.
JAMES HARTNESS.....Springfield, Vt.
H. G. REIST.....Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

WILLIAM H. WILEY.....New York

CHAIRMAN OF THE FINANCE COMMITTEE

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LEONARD WALDO (2)
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WM. H. BRYAN (1)
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CHAS. E. LUCKE (3)
H. DE B. PARSONS (4)

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PUBLICATION

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NOTE—Numbers in parentheses indicate number of years the member has yet to serve

SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus — G. T. Voorhees
A. P. Trautwein — Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet — H H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman* — F. R. Hutton
G. M. Basford — D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman* — L. D. Burlingame
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Calvin W. Rice

On International Standards for Pipe Threads

E. M. Herr, *Chairman* — Geo. M. Bond
William J. Baldwin — Stanley G. Flagg, Jr.

On Standards for Involute Gears

Wilfred Lewis, *Chairman* — E. R. Fellows
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On Power Tests

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Edward T. Adams — William Kent — Arthur West
George H. Barrus — Charles E. Lucke — Albert C. Wood

On Student Branches

F. R. Hutton, Honorary Secretary

On Arrangements for Joint Meeting in England

Ambrose Swasey, *Chairman* — Chas. Whiting Baker, *Vice-Chairman*
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W. F. M. Goss

Members Ex Officio

George Westinghouse, President — F. R. Hutton, Honorary Secretary
William H. Wiley, Treasurer — Calvin W. Rice, Secretary
Willis E. Hall, Chairman Meetings Committee

SOCIETY REPRESENTATIVES

1910

On John Fritz Medal

AMBROSE SWASEY (1)
F. R. HUTTON (2)
CHAS. WALLACE HUNT (3)
HENRY R. TOWNE (4)

On Board of Trustees United Engineering Societies Building

F. R. HUTTON (1)
FRED J. MILLER (2)
JESSE M. SMITH (3)

On Library Conference Committee

J. W. LIEB, JR., CHAIRMAN OF THE LIBRARY COMMITTEE, AM.SOC.M.E.

On National Fire Protection Association

JOHN R. FREEMAN
IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS
F. W. TAYLOR

On Advisory Board National Conservation Commission

GEO. F. SWAIN
JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS
FRED J. MILLER

NOTE—Numbers in parentheses indicate number of years the member has yet to serve

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1910

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J. R. Bibbins

SECRETARY
Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman (1), *Chairman*
G. I. Rockwood (2)
F. R. Hutton (3)
H. H. Suplee (4)
F. R. Low (5)

GAS POWER MEMBERSHIP COMMITTEE

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H. V. O. Coes
A. E. Johnson
F. S. King
A. F. Stillman
G. M. S. Tait
George W. Whyte
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

Wm. T. Magruder, *Chairman*
W. H. Blauvelt
E. D. Dreyfus
A. H. Goldingham
Nisbet Latta
H. B. MacFarland
C. W. Obert
C. T. Wilkinson

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
G. D. Conlee
R. S. de Mitkiewicz
L. V. Goebbels
L. N. Ludy
L. S. Marks
T. M. Phetteplace
G. J. Rathbun
R. B. Bloemeke
A. L. Rice
A. J. Wood

GAS POWER INSTALLATIONS COMMITTEE

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C. B. Rearick

GAS POWER PLANT OPERATIONS COMMITTEE

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C. J. Davidson
C. N. Duffy
H. J. K. Freyn
W. S. Twining
C. W. Whiting

GAS POWER STANDARDIZATION COMMITTEE

C. E. Lucke, *Chairman*
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E. T. Adams
James D. Andrew
H. F. Smith
Louis C. Doelling

Note—Numbers in parentheses indicate number of years the member has yet to serve

MEETINGS OF THE SOCIETY

THE MEETINGS COMMITTEE

WILLIS E. HALL (5), *Chairman* — L. R. POMEROY (2)
WM. H. BRYAN (1) — CHAS. E. LUCKE (3)
H. DEB. PARSONS (4)

Meetings of the Society in Boston

IRA N. HOLLIS, *Chairman* — I. E. MOULTROP, *Secretary*
EDWARD F. MILLER — J. H. LIBBEY

Meetings of the Society in St. Louis

WM. H. BRYAN, *Chairman* — ERNEST L. OHLE, *Secretary*
R. H. TAIT, *Vice-Chairman* — FRED E. BAUSCH
M. L. HOLMAN

OFFICERS OF STUDENT BRANCHES

INSTITUTION	BRANCH AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	CORRESPONDING SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	C. C. Allen	C.F. Hirschfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	G. F. Gebhardt	F. E. Wernick	W. E. Thomas
Leland Stanford Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	A. F. Meston	J. B. Bubb
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	H. A. Houston	J. M. Barr
University of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	B. L. Keown	C. S. Huntington
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York.	November 9	Chas. E. Lucke	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Morrill Mackenzie	Foster Russell
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	H. B. Cook	C. J. Malone
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	John S. Langwill	Karl L. Kraatz
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
Univ. of Nebraska, Lincoln Neb.	December 7	C. R. Richards	W. J. Wohlenberg	W. H. Burleigh
	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams